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T H E C R E A T I O N :
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N A T U R A L P H I L O S O P H Y :
I N F I V E V O L U M E S .

T H E T H I R D E D I T I O N , E N L A R G E D .

B Y J O H N W E S L E Y , A . M .

V O L . I I I .

These are thy glorious Works, Parent of Good,
Almighty! Thine this universal Frame,
Thus wond'rous fair! Thyself how wond'rous then!

MILTON.

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PART the FOURTH.

Of Earth, Water, Fire, Air, and
Meteors.

CHAP. I.

Of Earth and Water.

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THE Earth or terraqueous globe is a conge-
ries of many different bodies. It contains
sand, clay, various sorts of earth, stones, salts of
various kinds, sulphur, bitumen, metals, minerals,

and other fossils almost innumerable. Upon the earth are the waters, and on or near its surface, animals and vegetables of all kinds. But how was this whole mass formed into mountains, valleys, seas, rivers, and islands? Des Cartes advances one hypothesis, Dr. Burnet another, Mr. Hutchinson a third. And each world-builder advances plausible reasons for his own hypothesis. But none of those reasons are demonstrative: higher than probability they cannot go.

That the earth is round, manifestly appears from the eclipses of the moon, in all which the shadow appears circular, which way soever it be projected. The natural cause of its roundness, is the great principle of attraction, which the Creator has stamped on all the matter of the universe, whereby all bodies, and all the parts of bodies continually attract each other. By this means, as all the parts of bodies tend naturally to their center, so they take a globous figure, unless some other more prevalent cause interpose. Hence drops of quicksilver put on a spherical form, the parts strongly attracting each other, drops of water have the same form, when falling in the air, but are only half round, when they lie on a hard body, because their gravity overpowers their attraction. Yet the earth is not exactly round, but swells out towards the equator, and is flatter towards the poles, which is supposed to be occasioned by the diurnal rotation of the earth on its axis. By this means the greater diameter exceeds the less, about 34 miles. What the earth loses of its sphericity by mountains and vales is nothing considerable: the highest eminence being scarce equivalent to the smallest protuberance on the surface of an orange. The diameter of the earth is supposed to be 7967 miles.

In

In the terraqueous globe are 1. The external part, from which vegetables grow, and animals are nourished: 2. The middle part which is possessed by fossils, and extends farther than human labour can penetrate: 3. The internal, which some suppose to be a great Loadstone: some a large mass of fire: some a collection of waters: and others, an hollow space inhabited by animals, which have their sun, moon and all other conveniencies, peculiar to themselves. But indeed of that we know nothing. The deepest cavities natural or artificial, known to us, scarce penetrating a mile below the surface.

In the external part we meet with various Strata, which were doubtless formed by the general deluge. The exterior parts of the earth were then dissolved, and mixed with the waters in one common mass. Afterward they sunk, nearly according to the laws of gravity, the heaviest first, and the lighter in their order. So were these strata formed, with hardening by degrees, have continued ever since. It is probable, these lay more regularly at first, but have been much changed in process of time, and their order disturbed by earthquakes, vulcano's, and divers other causes.

The earth is nearer the sun at Christmas than at Midsummer, as appears both from the sun's apparent diameter being greater in December than June, and from its motion being then swifter. Hence it is that there are about eight days more in the summer half year from March to September, than in the winter half year from September to March.

That the earth moves round its own axis, not the sun and stars round the earth, may appear from this single consideration. All the planets revolve

in more or less time, as their orbits are greater or less. If then they moved round the earth, they must revolve in unequal times, according to their orbits; not all in the same time, in four and twenty hours, as they seem to do. Therefore, they do not move round the earth, but the earth, as the rest, round its own axis.

That it moves also round the sun, appears thus. All bodies, which turn round each other, must gravitate towards each other: consequently if the sun gravitates to the earth, so must the earth to the sun. Now it is demonstrable, that when two bodies gravitate to each other, without approaching each other in right lines, they both turn round their common center of gravity. But the earth being no more than a point to the sun, the common center of these two bodies, will be within the body of the sun itself, and not far from the center of it. The earth therefore turns round a point which is in the sun: consequently round the Sun. Indeed to suppose the earth at rest, destroys all the order and harmony of the universe, annuls its laws, and sets every part at variance with the others. It renders the motions of the planets utterly inexplicable, which are otherwise plain and simple.

Nor is the motion of the earth, whatever is vulgarly supposed, contrary to any part of the scripture. No other ideas are to be affixed to the words of scripture, than such as occur to one who looks at the thing spoken of. By the sun's rising therefore when mentioned in scripture, we are to understand no more than the sun's appearing again in the horizon, after he had been hid below it: and by his setting, his ceasing to appear. And when the sun and moon are said to stand

stand still, it means only, that they did not change their situation in respect of the earth: that the sun still appeared just *over Gibeon*, and the moon *over the valley of Ajalon*. If it be said, " But David speaks of the *Sun running its course*," we may answer over and above, the word here used does not mean the Orb or Body of the sun, but always his Rays or Beams.

2 It is probable Sand was once the exterior cover of the whole earth. All our northern mountains are, more or less, covered with it at this day. And the higher the mountain, the coarser the sand. The rivers rising in the mountains, still daily bring it down in large quantities. And that it has been so in all ages, since the first rains fell on the earth, seems highly probable, in that the mouths of rivers, and entrances of harbours are usually barred with it. And if you pierce deep into the low ground near rivers, you find this mountain-sand in great quantities: it was the more fit to be the general cover of the earth, because of its great hardness, and consequently durableness. Mountain Sand above all other, not being made (as much Sand is) by attrition, steadily keeps its original figure and magnitude.

All Sands are either natural or fictitious. Natural Sands are those which have been in the same or nearly the same state from the creation, diffused through all the parts of the earth. Sand viewed in a microscope, is no more than a parcel of little stones; doubtless therefore they must have begun to exist, and been formed by the same laws that stones were formed by. Now stones were formed first into hard and solid masses, in proportion to the quantity of similar materials, and proper cement. Where there was a great

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quantity of lapideous particles, and few heterogeneous mixtures, there strata, rocks, and large stones were formed. But where the lapideous particles were scattered and disunited by the intervention of other bodies, there small rubble, stones, gravel, grits, and the smallest and most numerous of all stones, Sand, coalesced into minute glebes. This probably was the process in every part of the earth; so that Sand is one of the primæval bodies, concreted at the same time with stones, upon the highest mountains, as well as in the valleys; and at the bottom of the sea, as well as upon dry land.

Besides this natural Sand, there is also a fictitious one, which owes its origin to the fretting of river or sea-water. For water always in motion, preys upon the stones, and grinds them by degrees into that stony powder which we call sand: hence it is that the sand of a particular stone, cove or bay, has generally the same colour, and in a microscope the same structure, as the rocks, and stones of the adjacent cliff, and the strata under the sea, upon which the waves are perpetually working, and driving into the sea what they dash off from those strata.

3. We have heard of large Bodies of Sand moving together in the deserts of Arabia. But has any thing of the kind been known in England? There has, and that very lately, It is not a century, says Mr. Wright, since our Sands, near Dornham, in Suffolk, first broke prison. In a warren near Lakenheath, an impetuous south west wind having broken the Sand of some Sand-hills, the Sand blew upon the adjacent grounds, which being much of the same nature, the thin crust of
barren

barren earth was soon rotted and dissolved by this Sand lying upon it, and thereby fitted to bear it company in its strange progress. At its first eruption the whole magazine of Sand could not cover above eight or ten acres of land. But it increased into a thousand acres before the Sand had travelled four miles. Above thirty years since it reached the pounds of this town, where for ten or twelve years it did no considerable mischief: because its course was then down the hill, which sheltered it from the wind that gave it motion. But the valley once past, it went above a mile (up-hill) in two months time. It over-run two hundred acres of good corn that same year. 'Tis now got into the body of this little town, where it has buried several houses. And the remainder have been preserved at more expence than they were worth. At the other end of the town divers houses are buried, and our pastures and meadows destroyed. A branch of the river Ouse, upon which we border for three miles together, is more than half filled up with sand. And had not this interposed to stop its passage into Norfolk, doubtless a considerable part of that county, had e're now been left a desolate trophy of this conquering enemy.

4. One of the most considerable parts of the earth is the Mountains. There is a remarkable irregularity in their figure, and (so far as we can judge) an entire neglect of order in their situation. The far greater part of them are hollow, and contain beds of stone, metals or minerals. And doubtless such there were from the creation, although perhaps not so high, steep, or rugged.

For these vast masses are not, as some have supposed, mere incumbrances of the creation : rude and useless excrescences of the globe ; but answer many excellent purposes. They are contrived and ordered by the wise Creator, for this grand use in particular, to dispense the most necessary provision of water, to all the parts of the earth ; without which neither animals could live, plants grow, nor perhaps fossils receive any increase. For was the surface of the earth even and level, there could be no descent for the waters, but instead of gliding along those gentle declivities, quite down to the sea, they would drown large tracts of land, and then stagnate and putrify.

Indeed without hills, as there could be no rivers, so neither could there be any springs, which we continually find in or near high grounds, very rarely on spacious plains. When we do find any there, it is generally at great and inconvenient depths. And even these are probably owing to hills, either near, or at some distance : as we may gather from the impetuous manner wherein these subterraneous waters break out, when wells are dug in the Lower Austria, or in several parts of Italy. And if there are some islands, which seem void of mountains, and nevertheless are well watered, in reality the whole mass of land is no other than one Mountain, descending gently and imperceptibly down, from the midland parts to the sea.

5. The Benefit of Mountains in general is not only, that vapours driven against them are condensed, so as to be precipitated through the chinks of the rocks, but that afterwards in their
bowels

bowels they are preserved till they form rivulets, and then rivers. Vapours would fall in rain or dew though there were no Mountains, but then they would fall equally, over considerable places of the globe at once, and so would be sucked deep in the ground, or make an universal puddle; whereas by means of Mountains they are perpetually pouring down in particular places, and treasuring up a constant supply to the rivers. Another considerable use of them is the determination of these rivers; for if there could have been rivers without Mountains, yet they could only have run in a strait line, if they had run at all; whereas by these eminences, placed up and down, they make innumerable turnings and windings, whereby they enrich, fatten, and water the soil of several different countries in one course, and at last disembogue in several mouths into the sea. Lastly, most hills are the nests of metals or minerals. These by the efficacy of subterranean heat, converting the adjacent earths into their substance, grow as truly as animals or vegetables. I just mention their use for the production, shelter, and nourishment of some sorts of vegetables and animals, which could not grow or live so well any where else. But from the whole we may see of what advantage these unsightly moles (as some thought them) are to the accommodations, and even necessities of life.

6. The Height of Snowden Hill, supposed the highest in Great Britain, is 1240 yards. But Skiddon Hill in Cumberland is 1760 yards high from the level of the lake beneath. And Cona-gra, which rises gradually from the head of the bay at St. Kilda, one of the western islands of Scotland.

Scotland, is 1800 yards high ; so that this may justly be stiled the Teneriff of Great Britain. The Height of several Mountains in France is as follows :

	Feet
Bugarach in Languedoc	3888
Le Puy de domme	4860
Le Courland	5088
Le Coote	5106
Le Cantal	5904
Le Mont d'or	6180
Le Mont Ventoux in Avignon	6216
The Height of the Pyrenean Mountains is,	
St. Barthelemi	7110
La Montagne des Mauffet	7548
Le Conigoe	8640

Probably these Mountains may vie in height with most in the known world. Yet above all these is the Stella Piz Hail, a steep Mountain in the Grisons, which is 9585 Paris feet above the level of the sea; a Height which the wild goats themselves scarce venture to ascend.

But Mr. Martel informs us, that the highest point of Mont-Blanc is higher even than this : that it is 2076 toises above the level of the Rhone, which added to the Height of this above the sea, makes 13115 Paris feet, or above two English miles, and two thirds of a mile. If so, this is the highest Mountain in Europe, and perhaps in all the world: unless you except Mount Atlas in Macedonia; which, according to the account of Riccioli, who measured it exactly, is 10,000 Italian paces high, carrying its top above the winds and clouds: a clear proof of which is, that whatever is written there in ashes or light sand, is found there, just as plain as at first, after several months or years.

“ But

“ But is not the celebrated Mount Atlas in Africa, the wonder of all ages, far higher than this ?” One who saw it, and travelled all over it, is best able to answer this question. He writes thus:

“ Barbary is bounded on the south by Biledulgerid, from which it is divided by Atlas, a chain of Mountains, but not of that extraordinary Height or bigness, which the antients attributed to it. Those parts of them, says Dr. Shaw, which I have seen, are rarely, if ever equal to some of the Mountains of our own island, and cannot any where stand in competition with either the Alps or Appenines. Atlas is a number of hills, usually 4, 5, or 600 yards high, with an easy ascent, and groves of fruit and forest trees, rising up one behind another. Only here and there is seen a rocky precipice, of a superior eminence.

The rivers of Indus and Ganges, before they enter the ocean, contain between them a large Peninsula, divided in the middle by a ridge of high hills, which runs from east to west, quite to Cape Comorin. On the one side is Malabar, on the other Coromondel. On the Malabar side it is summer from September till April; a clear sky, and scarce any rain. This is winter on the Coromondel side, every day and night yielding abundance of rain. So that as you cross the hills to St. Thomas, in little more than twenty leagues, you ascend the hill with fair summer weather, and descend with a stormy winter. There is a like ridge of hills in Jamaica running from east to west, through the midst of the island. On the south side of these there is summer from November to April, on the north side, winter, and so vice versa.

Hence it appears, that not the lessening the gravity of the atmosphere only, is needful to produce

duce rain, but likewise either a change of winds or a ridge of hills, to drive the particles of the vapours together. And hence it is that while the wind blows from north-east in Coromandel, and on the north-side of the mountains in Jamaica, there are continual rains, and constant fair weather on the south-side of the Mountains, and in Malabar. Whereas while it blows from the south-west, there are constant rains on the south-side of the Jamaica Mountains and in Malabar; but constant fair weather on the north-side of those mountains and in Coromandel.

This also may account for the singularity of seasons in Peru, which run southward from the line above a thousand leagues. It is divided into three parts, long and narrow: the Lano's or plains, which run along the sea-coasts, the Sierra's, which are hills with vallies intermixed, and the Andes, which are steep and craggy Mountains. The Lano's are, some ten leagues in breadth, some less, and some more. The Sierra is twenty leagues in breadth, and the Andes the same. It is remarkable, 1. That in the Lano's, the south and south-west winds continually blow. 2. That they never have any thunder, hail, snow, or rain, only sometimes a small dew. 3. On the Andes it rains almost continually. 4. In the Sierra, which lies between, it rains from September to April, and is clear from April to September. The reason is plain: the constant wind blowing over the Lano's, finds nothing to stop it, and drive its vapours into rain. But the Andes continually intercept these vapours, and so occasion continual rain. The Sierras being lower, intercept the vapours only from September to April, because then the sun being nearer the atmosphere is lighter, and consequently the vapours sink lower.

In

In regard to this, there are two or three acts of Divine Providence, which are highly observable. One is, that all countries throughout the world should enjoy the great benefit of Mountains placed here and there, at due and proper distances. According to the natural course of things, when the earth and waters were separated, and ordered to their respective places, the earth would have been of one even surface. The several component parts thereof must have subsided according to their specific gravities, and at last have formed a large, even spherical surface, every where equidistant from the center of the globe. But that instead of this form, it should jet out every where into hills and dales, is a manifest sign of the special providence of a wise Creator. Another sign of this is, that throughout the whole earth, the parts farthest from the sea are the highest: an admirable contrivance both for supplying all places with water, and for carrying off the superfluity of it.

And as the Mountains themselves are naturally disposed to be drier than the low grounds, so nature has provided for them, a more plentiful supply of moisture, unless for that very small part of them which ascends above the clouds and vapours. For beside the fountains which water them continually, they have more rains and dews than the valleys. They are much more frequently covered by fogs; and by stopping and compressing the clouds, as well as condensing them by their greater cold, they procure all the rain they want.

“ But how were the Mountains formed after the flood had dissolved the terraqueous globe ? ”
Probably thus. The smaller hills might easily be aggregated

aggregated by the mere force of the water. But the Mountains being of a denser substance, seem to have been elevated from beneath, in a convex form, by the violent force of subterraneous wind, water, and fire, heaving them up, and scattering them abroad in so many protuberances. And if this was done before the substance of the stones became fixed and indurated, then it is no wonder that the external wind likewise should leave so manifest tokens of its vehement impetuosity, in the extent and outward figure of them. This gives an easy, natural account, for the innumerable fissures, chasms, and disruptions, whereby so many Mountains are as it were fawn asunder, either across or length-ways. And hence many such apertures in the Mountains, are filled with a slimy matter which was afterwards indurated. In some of the Mountains of Norway, this projects in a range, about an ell in breadth, betwixt the other stony strata, through the whole length or bulk of the Mountain, and from the variety of its colours, makes a very pleasing appearance. Of these veins, some consist of marble or alabaster, some of agate, some white, red, or blue stone, which especially towards the sea, where the rocks are bare, form many curious variegations. Hence likewise there remain on the surface many detached blocks and fragments, scattered not only in the valleys and creeks, but on the tops of the highest Mountains. Many of these are of the bulk of a common house, and consequently too ponderous, to have been raised to such an immense height, by the hands or art of men.

But the largest Mountains may have been formed in the following manner. The sea-waters doubtless remained some time on the earth: and during

during that time the surface of the earth was the bottom of the sea, where every thing passed in the same manner as passes at the present bottom of the sea. Now the sea has always had a flux and reflux, and that most violent under the equator, where likewise the earth's motion causes a greater centrifugal force than any where else. Suppose then the earth was at first quite round, yet its diurnal motion, with the flux and reflux of the sea, would have raised by degrees the parts near the equator, by amassing there shells, mud and earth. And as this is performed daily, the water would carry at each time a small quantity of matter, which afterwards sinks to the bottom, and forms those parallel strata, which are every where found.

Thus in fact. On many shores the flux brings a great number of things along with it, and leaves them there. So that while it insensibly covers some lands, it abandons others, after adding thereto shells, earth and sand, which gradually accumulating, make a part of the continent.

On a coast against which the sea beats violently, it carries a little soil away at each tide. Yea, even where it is bordered with rocks, it wears them away by little and little. These particles the waters carry to a certain distance, where they sink in the form of a sediment, and form the first stratum, which will soon be covered by another, and so with more and more. Hence in time a Mountain will be formed in the bottom of the sea, entirely like what we see on the land.

Such eminences lying in the same direction with the waves that produced them, form by degrees a chain of mountains. "But how come Mountains whose top is composed of rock, to have only
earth

earth or sand for their base, which may often be seen in the neighbouring plains, to a considerable distance?" We answer, the water first transported the sand that formed the first layer at the bottom of the sea. Afterward the more firm and weighty substances were attacked, and brought by the Waters in an impalpable powder. And this powder of stone formed the rocks which now cover these eminences.

These causes act with more force under the equator, as the winds are there more uniform, and the tides more violent: and accordingly the greatest chain of mountains is near the equator. Those of Africa and Peru are the highest we know, which after traversing whole continents, stretch to very considerable distances, under the waters of the ocean. The mountains of the north are not equal to these. Moreover the number of isles in the northern seas is inconsiderable, while there is a vast quantity under the torrid zone: and an island is no more than the top of a mountain.

It is then doubtless the general flux and reflux of the sea, which has produced the greatest mountains. But others we may ascribe to currents, winds, and other irregular agitation of the sea, which must by their various combinations, infinitely vary the direction of the tides. They are the smallest of all which owe their rise to earthquakes, or other accidental causes.

But how shall we account for the formation of the Iron Mountain, near Taberg, in Sweden? It is situated in a mountainous part of the country, covered with sand, near forty leagues from the sea. It is an entire mass of rich iron ore, the perpendicular

perpendicular height whereof is above four hundred feet, and its circumference three English miles. Opposite to it is a valley, through which flows a small river. No ore is found beyond the foot of it, nor on the neighbouring plain, so that it appears as if the mountain had been artificially laid on the sand. For it has no roots like other mountains, nor does its substance penetrate the ground. It has all over, many perpendicular and horizontal fissures, filled with pure sand: in the inner parts whereof bones of stags and other animals are found.

No hypothesis hitherto advanced to account for the formation of mountains, will at all account for this. The bones found therein shew it was owing to some ruinous cause. But what that cause was, must in all probability ever remain a secret.

No less unaccountable are some of the mountains in Iceland, termed by the natives, Jokeler. From the tops of these continually flow large streams of a thick, footy, stinking water. These occasion lakes which increase in bulk, and again diminish, and change their appearance almost every day. Hence paths are seen in the sand made by travellers that passed the day before. When followed, they lead to a large pond or lake, which obliges them to go two or three miles round, and then they come to the very path opposite to that which they were obliged to leave. But in a few days the lake is, as it were vanished, and the uninterrupted path appears again.

7. A body that yields easily to the touch, and whose parts making but little resistance against
being

being divided, move among themselves with great facility, is usually termed a Fluid. Liquids are a sort of Fluid which assume the figure of the vessels they are contained in, and always keep their upper surface in a plain, parallel to the horizon. Such are Water, oil, mercury, which are distinguished from other fluids, by the parallelism of their surface, in consequence of their weight, and the intestine motion of their parts all manner of ways. That they have such a motion, plainly appears, from their dissolving hard bodies. Put a piece of copper into a glass of Aqua-fortis, and there is first an effervescence, then the copper diminishes, and at last disappears. And what strong waters are with regard to metals, other liquids are to other substances. Each of them is a dissolvent, more or less, according to its component particles. Now it is plain that dissolution supposes motion, and is the effect of it. There is therefore in all liquors an intestine motion, from which this effect results.

Water is a transparent liquid, capable of heat and cold, and of being rarefied into vapour. But it is not capable of being condensed, by any method yet known. It is of itself without smell or taste, and liable to putrefaction. It is heavier by many degrees than air, and insinuates where air cannot enter. These properties do unquestionably depend on the figure and texture of its parts. But these, after our most curious researches, it is not possible to know with certainty. Dr. Boerhaave says, No one ever yet saw a drop of pure water. It is never pure from salts. For all Water contains air, and all air contains salts.

The particles of Water are generally allowed
to

to be round. This figure indeed is probably inferred from its fluidity. Allowing then the particles of it to be round, fluidity must be an essential property of all quantities and assemblages of it. For take any mass of round bodies, (bullets for instance, pebbles, or the like) they will not cohere or rest by one another without force, but will flow on every side, till they meet with such resistance from external bodies, or their internal gravitation, as shall prevent farther motion.

The particles of water are unalterable, for passing into so many bodies, and through such alternate extremes of heat and cold, if they had not preserved their essential properties constantly, moisture since the beginning of the world, must have very sensibly diminished. But seeing no such deficiency appears, and that springs, rains, and rivers, are as abundant now as they antiently were (as by the rising of the Nile for many ages, among other reasons may appear) we are to conclude, though waters may be transplanted, they can neither be transmuted nor destroyed. And wherever removed they will make their appearance again when at liberty, in the same liquid state as they were before.

The particles of water are exceeding small: for they may be so divided from each other, that one square inch of common water shall when rarified, fill a space of 14000 square inches. And it is computed that at least 13000 particles of Water may be held on the point of a needle. By this it appears, that what we call water is an assemblage of small transparent globules, which are composed again of an infinite number of smaller particles or atoms of this elementary liquor.

Water

Water seems to be diffused every where, and mixed with all bodies. Fire itself is not without it. Place salt of Tartar near the hottest fire, and it will imbibe Water, and thereby in a short time, considerably increase in weight. So a pewter vessel with ice in it, brought up from a cold vault into the hottest room, in a dry summer-day, is immediately covered with little drops of Water, which is gathered from the air, and condensed by the coldness of the ice.

Indeed the quantity of Water which is afforded by the dryest bodies is surprizing. Oil of vitriol long exposed to violent fire, to separate it from all its water, by only standing a few minutes in the air, will afford as much as at first. Hartshorn kept forty years, and turned as hard and dry as any metal, so as to strike fire with a flint, yet distilled in a glass vessel, will yield an eighth part of its quantity in water. Bones dried five and twenty years, and almost as hard as iron, have by distillation yielded half their weight in water. Yea, the hardest stones, ground and distilled, always afford a portion thereof. All animals and vegetables grow out of water and salts, and by putrifaction return to the same.

The chief properties of Water are, 1. It is next to fire, the most penetrative of all bodies. So that a vessel through which Water cannot pass, will contain any thing. Only some oils will pass through those wooden vessels, which contain water. Not that their particles are more penetrative; but those woods abound with rosin. This the oil dissolves, and then makes its way through the spaces left thereby. Water also by degrees makes its way through all wood, and is
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only retainable by glass and metals. It finds its way where air cannot, as through leather, which air cannot penetrate. Again. Air may be retained in a bladder: but water oozes through. Yea, experiments shew, it will pass through pores ten times smaller than air will. By this very quality it is fitted to enter into the composition of all bodies, animal, vegetable, and fassile; with this peculiar circumstance, that by a gentle heat it is separable from them again. By this, joined with its smoothness, it is fit to convey the nutritive matter of all bodies. Passing so readily, it never stops up the pores, but leaves room for the following supplies. And yet 2. Water, which so easily separates from most bodies, firmly coheres with some: yea, binds them together in the most solid masses. So mixed with alhes, it gives the utmost firmness. The alhes, for instance, of an animal, wrought up with pure water into a paste, and baked with a strong fire, grows into a coppel, which bears the utmost heat of a refiner's furnace. It is in truth, by the glutinous nature of water alone, that our houses stand. For take this out of wood, and it becomes alhes; out of tiles, and they become dust.

Indeed all the stability and firmness in the universe, are owing to Water alone. Thus stone would be incoherent sand, did not Water bind it together. And thus of Water and clay we make earthen vessels, of the utmost hardness and closeness. And these, though appearing perfectly dry, yield when distilled, an incredible quantity of Water. The same holds of metals, parings or filings, which by distillation, yield water plentifully. Yea, the hardest stones, sea-salt, nitre, vitriol,

vitriol, are hereby shewn to consist chiefly of Water.

Hence we learn, that the component particles of Water are, 1. Infinitely small, whence their penetrative power. 2. Exceeding smooth and slippery. Hence their fluidity, and easy separation from other bodies. 3. Extremely solid. 4. Perfectly transparent. 5. Hard, rigid, and inflexible: as appears from the absolute impossibility of compressing them.

Salts melted in water, do not fill the vessel in proportion to their bulk. It follows, that there are spaces between the particles of Water, to admit those of the salt. Hence also we gather, that the watry particles are extremely solid and inflexible, since notwithstanding those spaces, no power can compress, or force them nearer each other.

8. When the particles of Nitre that float in the air, wedge the particles of water together, they become Ice. The air lodged in the pores of the water, is then greatly expanded. Hence the water is lighter than before: but at the same time it is less transparent: perhaps because the passage of light is hindered by the interposal of these nitrous particles.

It is observable. 1. That all liquids, except oil, dilate in freezing and grow lighter. Nay, even after they are thawed, they are considerably lighter than before: 2. That water will not freeze *in vacuo*: 3. That water which has been boiled does not readily freeze: 4. That water covered with oil of olives does not freeze readily; covered with nut oil, not at all: 5. That nut oil, oil of turpentine and spirits of wine will not freeze at all: 6. That
frozen

frozen water is covered with wrinkles, something like rays drawn from a center to the circumference.

Though fluids are dilated near a tenth of their length, metals are shortened by frost. If vessels made of metals, however thick and strong, be filled with water, close stopped, and exposed to frost, the water will burst the vessels. A strong barrel of a gun, thus filled and stopped, will rend the whole length.

Dr. Plot observes, that rivers are always found to freeze first at their bottom. The same is observed by watermen in the Thames, who not only feel it at the bottom with their poles, some days before the surface is froze over, but see it rise up from the bottom, so as to dart up in pieces edgewise, half a foot, sometimes a foot above the surface. In this posture it continues a little time, and then turning flat upon the water swims along the stream, till it meets with other pieces, which if the frost continues, all harden into one, till the river is froze over.

“ In a part of the Thames, where there was very little stream, I found the water, (says Dr. Hale) in a cold morning froze one fifth of an inch thick, under which I saw a bed of Ice at the bottom. Breaking away some of the upper Ice, I took up some of the lower Ice, which was about half an inch thick. It adhered close to the bottom, where the stones and sand were incorporated with it. When it freezes to a considerable thickness, it will raise up with it from the bottom, the fishermen's osier wheels, although they are sunk down with stones or bricks tied to them.

“ Standing waters indeed freeze first at top, because they are coldest there: whereas in a stream the upper and lower waters being continually blended together, are equally cold; and the upper water meantime having more motion, cannot freeze so soon. But here, where the motion of the water was so small, its surface was froze as well as the bottom, though not so thick: whereas the main river, where its motion was greater, was not froze over, though cakes of Ice were continually rising from the bottom.”

It has been commonly supposed, that fluids not only dilate, but evaporate by cold. And this has long passed for an incontestible truth. Yet it is altogether a mistake. From later experiments it undeniably appears, 1. That cold does not increase but lessen the evaporation of water, if it be not exposed to the agitation of the air: 2. That the evaporation of water depends on an intestine motion, which it preserves as long as it is liquid, and that the air only contributes thereto, by continually transporting the particles detached from the surface, and thereby giving other particles room to disengage themselves: 3. That frozen water does not evaporate at all, if it be kept from the agitation of the air: 4. That the diminution observed in Ice exposed to the open air, is not from any evaporation, but is the effect of a fine rasping by the wind, rubbing against it and carrying off its finer particles. And what is thus detached from Ice is only a very fine dust, not more different from Ice than the dust of free-stone, cut from the stone itself.

This dust carried by the wind produces intense cold.

cold. Nor is it always invifible. The air near Hudfon's Bay is often filled with particles of Ice, fine as hairs, and fharp as needles; which if they ftrike againft the hands or face, pierce the fkin and occafion painful blifters.

The natural ftate of this globe feems to be in an intermediate degree between heat and cold. And this natural warmth of the earth is what fecures many fprings from being frozen: the froft in England feldom penetrating the earth, more than fourteen inches below the furface. Even in Sweden bubbling fprings do not freeze at all, while the ftanding waters freeze three ells deep.

In the lakes of Sweden the Ice often cracks, with a rupture nine or ten feet deep, and many leagues long, and with a noife like cannon. Hereby the fifhes get air, fo that few of them are deftroyed. In Mofcow the earth is often cleft by the froft, a foot broad and many yards long. In the mountains of Switzerland, there are vaft maffes of ice, which have lain there for many centuries. At certain times thefe crack, and by thofe cracks one may guefs at the immense thicknefs of them: fome of the cracks being three or four hundred ells deep, though none of them have ever gone through the whole thicknefs of the Ice.

We need not then be furprized, at the effects of fevere froft on trees and other vegetables. How thefe are hurt in hard winters is eafily underftood, if we confider, that water when frozen, takes up more fpace than it did before: that all trees, efpecially thofe that fhed their leaves, drink in a large quantity of moifture in fummer, and that the veffels of fmall twigs are larger in proportion than thofe of the trunk, and confequently

contain more moisture. It follows, that being surprized by an hard winter, before their juices are diminished, or changed into a glutinous nature, which does not so easily freeze: the vessels of the tree must necessarily burst. Consequently their juice must be extravasated, and so cause, as in animals, the death of the tree, by a kind of bleeding, which nothing can stop.

In the great frost in 1683, oaks, ashes and walnut-trees were cleft in two, and frequently with a terrible noise, and not only their bodies, but their branches and roots also. In 1708, the frost was almost through all Europe, except Scotland and Ireland. All the orange-trees and olives in Italy, Provence and many other countries perished, and all the walnut-trees in France, with an infinity of other trees. In England most of the bay-trees, hollies, rosemary, and even furze perished. The sap also of wall-trees stagnated in the branches, and produced disorders resembling chill-blains. And the very buds of the finer trees were quite killed, and turned into a kind of mealy substance.

In 1728, toward the end of November, the wind blew exceeding cold, followed by so heavy a snow, as in one night broke off large arms of many ever-green trees. At this time also, there was a great number of large trees disbarked. Two West-India Plane-trees, in particular, in the physic-garden at Chelsea, which were near forty feet high, and a fathom in circumference, were disbarked almost from the bottom to the top, on the west side of the trees. And it was observable, that whatever trees were disbarked, it was on the west or south-west side.

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On the fourteenth of December, 1759, there was at Petersburg, the most excessive cold weather that ever was known, even to 205 degrees of De Lisle's Thermometer. At that time Professor Braun repeated Fahrenheit's experiments, in order to produce excessive cold by means of Spirit of Nitre combined with snow. He saw with surprize, the quicksilver in the other Thermometer descend even to 470 degrees: there the quicksilver remained fixed in the open air, for the space of a quarter of an hour, and did not begin to rise, till it was carried into a warm room. He repeated the same experiment, first with the same, and then with another Thermometer, with the same success. But as Mr. Braun had not broken the glasses, he could only at that time form a conjecture. On the 17th he produced again cold equal to that of the 14th, and communicated his discovery at a meeting of the Academy. On the 25th of December in the morning, between nine and ten, De Lisle's Thermometer was at the 199th degree of cold, and Mr. Braun, as well as Professor Æpinus, repeated this experiment. As soon as the former observed the quicksilver immoveable in the Thermometer, he broke the glass, and found the quicksilver frozen, but not entirely: Mr. Æpinus's Thermometer fell with extreme rapidity, almost to the 500th degree, and in breaking the glass from below, he found the quicksilver contained in it absolutely frozen. Both the gentlemen found, that the quicksilver, thus rendered solid, bore hammering and extension, like other metals; but being exposed to the open air, it recovered its former fluidity in a little time.

Mr.

Mr. Æpinus went farther, to examine the quicksilver when it was made solid. He poured quicksilver into a glass tube, as thick as one's finger, closed at the bottom, but open at top.

The quicksilver in this cylinder, which was about one inch and half long, froze in three quarters of a minute; and became solid, perfectly resembling other metals. Mean time it continually contracted, its surface, which was at first pretty high, soon sunk very low, and the cylinder of frozen quicksilver sunk to the bottom of the fluid quicksilver. We know the contrary happens to water frozen and other fluids, which extend as they become solid, and their ice swims in the fluid matter, of which they were produced.

The bodies of Ice in the northern seas, near Hudson's Bay are surprizing: some of them are immersed an hundred fathoms or more, under the surface of the ocean. They stand a fifth or sixth part above, and are three or four miles in circumference. These floating mountains owe their durable nature, to a cause not usually observed; that is, to their not being common ice, but the ice of sea-water. If a phial of sea-water be exposed to the air in frosty weather, till flakes of ice are formed therein, and then set in a warm room, still the flakes will remain a long time undissolved, and if they are taken out, and exposed at a small distance to the fire, they will not run into water, as common ice would do, but will by degrees evaporate, leaving only a little white salt. It is easy then to conceive, that the immense masses of this Ice, found in the Northern Seas, will continue undissolved throughout the year, and at the return
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of the freezing season, grow larger and larger every year, by the freezing of more Ice about them.

On the contrary, there are some waters, which will not freeze at all. The Lake Nefs in Scotland never freezes, be the winter ever so severe. Yea, while every thing round is frozen, its water run smoking for six miles down the river into which they are discharged; and from this smoke there rises a sort of fog, which overspreads the country, for several miles. Near the lake is a mountain, on the summit of which there is another lake, which is always full, summer and winter. Due west from the river, there is another lake, two miles long and six broad. The middle of this is sometimes dry, and then plainly appears to have been once an inhabited country. There are many tumuli to be seen under water, one of which is accessible at low water. And in this urns have been found, which leave no room to doubt of their having been burial places.

There are likewise in Scotland other lakes, which freeze only at peculiar seasons. A little lake in Stratherick, never freezes over, be the frost ever so sharp till February. But after the first part of this month, a slight frost will freeze it over in a night's time. There are also two other remarkable lakes in the same country. The one Loch Monan, which is considerably large, observes the same rule, freezing over in February with a slight frost, but never before, be the season ever so rigorous. The other in Straglash has a contrary quality. It lies between two high hills, and is itself considerably above the level of the rest of the country.

This freezes continually, having Ice in the middle, even in the hottest summer months, while the sun by reflection from the hills on each side, gives a very considerable heat. There are many other lakes in the neighbouring country which yet have no such property: so that this, and the property of the two other lakes, must be owing to some peculiar cause. The herbage about the sides of the lake last mentioned, has a kind of perpetual spring, which continues throughout the whole year, and is much esteemed by the country people, for feeding cattle in one month, more than the best land in the country will do in two. The lake is very deep, and the water does not manifest any particular quality.

9. Rain and snow which rise in vapours, both from the earth and waters, descending on hills, sink through the earth, till they meet with a bed of clay or stone. This retains the water and gathers it together, in a larger or smaller basin, till running over the edge, it makes itself a way, and rises in a Fountain. Hence issues a rivulet, many of which joining together, constitute a River, which continues its course, till it empties itself into the grand receptacle of water, the sea.

But it has been asked, "Is there a sufficient quantity of vapours raised, in the ordinary course of nature, to supply the demand of Fountains and Rivers?" We answer, there is abundantly sufficient, from the surface of the sea alone, leaving the earth out of the account. For it has been shewn by clear experiments, 1. That water salted to about the same degree as sea-water, and exposed to a heat equal to that of a summer's day,
did

did from a circular surface, eight inches in diameter, evaporate six ounces in 24 hours. If so, the thickness of a skin of water evaporated in two hours, is the 53d part of an inch. But were it only a 60th, it would exhale the tenth of an inch in two hours. And on this principle every ten square inches of the surface of water, yield in vapour a square inch of water daily: each square foot half a pint: every space of four foot square, a gallon: a mile square 6914 tons: a quantity abundantly sufficient to furnish, both dews, rains, springs, and rivers. So that we need not have recourse for supplies to the great abyss, whose surface, at high water, is surmounted several hundred feet, even by ordinary hills: and some thousands, by those vast mountains, from whence the largest rivers take their course.

Nevertheless we may allow a different rise to those springs, which ebb and flow with the sea: as likewise to those lakes whose water is salt, and which have sea-fish in them, although they have no communication with any sea, by any visible passage.

To explain this a little more at large. It is evident from experience, that a vapour is perpetually rising from the sea, rivers, and lakes. The winds carry this vapour through the atmosphere, in the form of a cloud or mist. When it meets with a colder air, or is stoppt by mountains, it condenses, and falls to the earth. As it falls, it finds several chinks and crannies, through which it insinuates into the mountains, and lodges there, till increasing its store, it bursts out and takes the name of a Fountain.

That this is really the case, will easily be allowed, by all who seriously consider, 1. That

the vapours rising from the sea, are more than sufficient to supply both the surface of the earth, and the rivers with water, 2. That the mountains by their particular structure, arrest the vapours that float in the atmosphere, and having collected them in their reservoirs, dismiss them again through their sides, either in perpetual or intermitting currents.

With regard to the first, it has been shewn, that every ten square inches of the surface of the sea, yields a square inch of water daily; every square mile 6914 tons: and pursuing the same proportion, every square degree (or sixty nine English miles,) will yield 33 millions of tons. Now if we suppose the Mediterranean to be 40 degrees long, and 4 broad at a medium, (which is the least we can suppose) its surface will be 160 square degrees: from whence there will in summer evaporate daily 5280 millions of tons.

The Mediterranean receives water, (to say nothing of small and inconsiderable streams) from eight large rivers, the Iberus, the Rhine, the Po, the Danube, the Neister, the Borysthenes, the Tanais and the Nile. Now suppose each of these conveys ten times as much water to the sea as the Thames. The Thames has been shewn to pour daily into the sea 203 millions of tons. Therefore all those rivers will produce 1827 millions of tons. But this is little more than one third of the quantity daily evaporated from the sea. How prodigious a quantity then remains for rains and all other purposes?

Let us observe, Secondly, how the mountains arrest, and collect these vapours, and then discharge them in springs.

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The tops of mountains in general abound with inequalities, cavities, grottos and gaping cells. The floating vapours are stopt by these and by their pointed summits, and being condensed thereby, precipitate in water, easily penetrate through sand and lighter earth, and gather in basons of clay or stone, till they overflow and work a passage through the side of the mountain.

And yet we need not deny, that some springs may arise from the sea, or the great abyfs: those in particular, which at all times afford the same quantity of water. Some of these are found in almost every country. There is one near Upminster in Essex; which in the greatest droughts, and when all the brooks are dried up, is little, if at all diminished. And in the wettest seasons, it is not increased, unless violent rain falling into it, or running into it from the higher grounds, raise it for a day, or a few hours.

As to the manner how the water rises in such springs it may easily be represented, by putting a small heap of sand in a bason, and then pouring in water. Here the sand will represent the dry land, and the water the sea round about it. And as the water in the bason rises, to or near the top of the heap, just so do the waters of the sea rise, to the top of the land with which it communicates,

10. Some think the earth entirely covered the Sea, till at the deluge *the fountains of the great deep were broken up*. And it is highly probable, there is still an abyfs of waters within the earth, which has an uninterrupted communication with some part of the outward sea.

The immediate cause of the deluge, was probably

bably that comet, which (as Mr. Whiston shews) passed toward the sun, just before the earth, on the first day of the deluge. The consequence of this must be, that when it came below the moon, it would raise a vast and strong tide, both in the waters that were on the antediluvian earth, and also in the great abyfs, which was under the crust of the earth. This tide must increase all the time that the comet was approaching toward the earth; and would be at its greatest height, when the comet was at the least distance from it. By the force of this internal tide, as well as by the attraction of the comet; the abyfs which was nearly round before, would then become oblong. And this must immediately extend, and then burst the incumbent crust. And thus, according to the expression of Moses, *the fountains of the great deep were broken up.*

Again. As the same comet for a considerable time involved the earth in its atmosphere, it must have lost a vast quantity of its vapours, most of which would fall on the earth in violent rain. And thus *the windows of heaven were opened.* To remove this vast orb of water, he supposes a mighty wind to have risen, which dried up some, and forced the rest into the abyfs again, through the clefts by which it came up. Only part of it stayed in the channel of the ocean, now first made to receive it, and in the lesser cavities, placed up and down on the surface of the globe.

The present distribution of the waters and the dry land, though it may seem rude and undesigned to a careless view, yet is admirably well adjusted to the use and conveniences of our world. In the first place, they are so distributed all the world over, that there is a just æquipoise of the whole globe.

globe. The Northern balances the Southern Ocean; the Atlantic, the Pacific Sea. The American dry land is a counterpoise to the European, Asiatic, and African. In the next place, the waters are so admirably well placed about the globe, as to afford sufficient vapours for clouds and rain, to temper the cold of the northern and southern air, to mitigate the heats of the torrid zone, and to supply fresh waters to fountains and rivers. Nay, so abundant is this great blessing, that we have more than a bare sufficiency, even a surplussage of this useful creature : and yet so well ordered, as not to drown the earth, not to stagnate, putrify, or annoy its inhabitants; but to glide gently through convenient channels back again to its grand fountain, the Sea : and many of the rivers through such large tracts of land, and to such prodigious distances, that it is a wonder the fountain should be high enough, or the sea low enough for so long a conveyance. Witness the Danube and Wolga in Europe, the Nile and Niger in Africa, the Ganges and Euphrates in Asia, with the Amazon's River and Rio de la Plata in America. No accidental currents or alterations of the waters themselves, no art or power of man, nothing less than the power of the Almighty, could ever have made or found, so long and commodious declivities and channels, for the passage of those waters.

11. The largest Rivers of Asia, are, the Hoanho, in China, which is eight hundred and fifty leagues in length : the Jenisca of Tartary, about eight hundred leagues in length, from the Lake Selinga to the Icy Sea : the Oby in Siberia, of near eight hundred leagues, running from the
Lake

Lake of Kila into the Northern Sea: the Amour in Eastern Tartary, whose course is about five hundred and seventy-five leagues, from its source to its entrance into the Sea of Kamtkatska: the Kiam in China, five hundred and fifty leagues in length. The Ganges, one of the most noted rivers in the world, is about as long as the former: it is visited annually by several hundred thousand pilgrims, who pay their devotions to the river as to a god; for savage simplicity is always known to mistake the blessings of the Deity for the Deity himself. Next to this may be reckoned the celebrated river Euphrates: this rises from two sources northward of the city of Erzerum in Turcomania, and unites about three days journey below the same; from whence, after performing a course of five hundred leagues, it falls into the Gulf of Persia. The river Indus is extended, from its source to its discharge into the Arabian Sea, four hundred leagues.

The largest rivers of Africa, are, the Senegal, which runs a course of eleven hundred leagues: and the celebrated river Nile, said to be nine hundred and seventy leagues from its source in Upper Ethiopia, to its opening into the Mediterranean Sea.

This river, which the natives call Abava, that is, the Father of Rivers, rises first in Sacala, a province of the kingdom of Goïama, the most fruitful in all Abyssinia. In the eastern part of this province, on the declivity of a mountain, are two springs, each about two feet diameter, a stone's cast distant from each other, which are the real source of this celebrated river. Its waters, after the first rise, run east about a musket-shot; then turning to the north, continue hid in the

the grafs and weeds, for about a quarter of a league, and discover themselves for the first time among some rocks, a pleasing sight to those who have read the fabulous accounts of the ancients. It flows thence with a very small stream, but soon receives such an increase from various rivulets, that not above three days journey from its source, it is near a mile broad. After running nine or ten leagues farther, it enters the Lake of Dambia. It crosses this at one end, with such rapidity, that the waters of the Nile may be distinguished through the whole passage, which is six leagues. Fifteen miles farther it rushes from the top of an high rock, and forms one of the most beautiful cascades in the world. The fall of this mighty stream from so vast an height, makes a considerable noise. Yet the neighbouring inhabitants are not deaf, but hear just as well as others. After this cataract, the Nile again collects its scattered stream, and flows on through various nations. Hence we may learn, that it is impossible to arrive at the source of the Nile, by tracing its channel from the mouth, there being so many cataracts in the way, which no vessel can pass.

In Abyssinia from June to September, there is no day without rain. Now the Nile receives in its course all the brooks, rivers, and torrents, which flow from the Abyssian mountains. These necessarily swell it above the banks, and fill the plain of Egypt with the inundation. This comes regularly in the month of July, that is, three weeks, after the beginning of the rains in Ethiopia.

The water of the Nile is so delicious, that the Turks excite themselves to drink of it by eating salt. When the Egyptians leave their country, they speak of nothing but the pleasure they shall find

find at their return, in drinking the Nile water. All those who have tasted of it, allow, that they never met with the like in any other place. In truth, when one drinks of it the first time, it seems (says Maserier) to be some water prepared by art. It has something in it inexpressibly agreeable and pleasing to the taste. But to some, it appears to have too much sweetness. It is likewise salutary in the highest degree. Drink it in what quantities you will, and it never incommodes you.

It seems peculiar to the water of the Thames, that in eight months time it acquires a spirituous quality, so as to burn like spirits of wine. Even when it stinks, it is not unwholesome: men who were obliged to hold their noses, yet drank of it all the way to the East-Indies, and found no inconvenience. If you take out the bung from any cask that stinks, and let the air come in, it will be sweet in twenty-four hours. If you take a broom-stick, and stir it well, it will be sweet in four or five hours. It casts a black lee to the bottom, which remixing with it, causes a third or fourth fermentation, after which it stinks no more. But though Thames Water does not putrify when it stinks, most other water does, and is at that time very dangerous to drink.

The Cataracts of the Nile are probably less remarkable than that of Niagara, in Canada. The fall of this is about six leagues from Fort Niagara. The whole course of the river for two leagues and an half below the great fall, is a series of smaller falls, one under another. The rocks of the great fall cross the river in almost a semicircle.

cle. Above the fall, in the middle of the river, and parallel with the sides of it, is an island above four hundred yards long. The lower end of this island is just at the perpendicular edge of the fall. On both sides of this island runs all the water that comes from the lakes of Canada, which indeed are rather seas than lakes, receiving many large rivers. When the water approaches the island, it runs with an amazing swiftness, and before it comes to the fall, is quite white, and in many places is thrown high into the air. Looking up the river from the fall, you see it is exceeding steep, resembling the side of an hill. When this vast body of water comes to the fall, it throws itself down perpendicular. To see this rush head-long down so prodigious a precipice, strikes the beholder in a manner not to be expressed.

It falls one hundred and thirty-seven feet. When the water is come down to the bottom, it leaps back to a great height in the air: at a little distance it is white as snow, and boils like a cauldron. The noise of it in fair weather is heard fifteen leagues, yea, many times at Niagara. From the place where the water falls, abundance of vapour rises, resembling a very thick smoke. When it is calm this rises high in the air. If you go into this vapour, in a few minutes you will be as wet as if you had been under water. In a calm morning, you may see it rising in the air, at the distance of many leagues. And a person unused to it, would be apt to think, that all the forests thereabouts were on fire.

But of all parts of the world, America supplies the largest rivers. The foremost of these is the great river of Amazons, which from its source in
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the Lake of Lauricocha, to its discharge into the Western Ocean, performs a course of more than twelve hundred leagues. The breadth and depth of this river are answerable to its vast length; and where its width is more contracted, its depth is augmented in proportion. Next to this is that of St. Laurence, in Canada, which after a course of nine hundred leagues, pours its collected waters into the Atlantic Ocean. The river Mississippi is more than seven hundred leagues in length. The river Plata is more than eight hundred. The river Oroonoko is seven hundred and fifty-five leagues in length, from its source to its discharge into the Atlantic Ocean.

The glory of other rivers increases in proportion to the length of their course. With the Rhine it is quite the reverse. For some hundred miles it pours on with a vast force. But at Fort Scheneken it divides, and one half of its waters takes the name of Wahall. The Yssel robs it of another part, a little above Arnheim. About twenty miles lower, at the town of Duerstadt, it separates again. Here its principal branch takes a new name, and is called the Leck. The poor, little, stripped rivulet turns to the right, retaining still the old name of Rhine, and passes on to Utrecht, where it is divided a fourth time. There the Vecht breaks off, and the little thread of water, still called the Rhine, passes quietly to Worden. At length it comes to Leyden, and faintly finishes its course, by losing the small remainder of its waters in two or three canals.

The cause of the Rhine's fate is well known. It was an earthquake which shook the Downs, in
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the ninth century, and filling the mouth of this river, forced it to return, and seek a new passage. The Leck was then scarce worth notice: but the waters of the Rhine, which were driven back, swelled and deepened its channel: and the entrance of the sea has been ever since shut against the ancient course of the Rhine. It is supposed, that Zealand was then divided into the several islands we see now: and that those lands, woods, and meadows, which were between Amsterdam and the Texel, were overflowed and covered with the waters still remaining, and known by the name of the Zuyder Sea.

The Lake Baiacal, in Siberia, is the greatest fresh water lake yet discovered. It extends in length above five hundred leagues, and is from twenty-five to eighty leagues in breadth. It is every where deep and navigable. The water is extremely clear, and abounds with fine fish. It receives abundance of rivers, but none runs out of it, besides one, the Angara.

Salt Lakes are common in many parts of Siberia. Some contain a pure, white salt, fit for use, which in summer is chrySTALLIZED by the heat of the sun, and forms a crust on the top of the lake. Springs of salt-water sometimes rise in the midst of fresh water. One of these rises through a rock, in the bed of the river Angara. Thirty leagues above this, there is a hill thirty fathom high and two hundred and ten long, consisting entirely of rock-salt. There are some lakes, which were fresh some years since, but are now salt: some have by degrees dried up; others appear, where formerly it was dry ground. And
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some of these, which at first had no fish, are now plentifully stocked therewith. The natives say, ducks and other birds that live upon fish, carry their eggs from one lake to another.

Three leagues east of Damascus is a lake ten or twelve leagues long, and five or six broad. This continually receives the waters of many rivers; yet never overflows its banks. Above thirty leagues from it, there is a river, which is called the Dog-River. From under a large, vaulted rock, through an opening twelve or fifteen feet high, and twenty or twenty five broad, issues continually a vast body of water, which gives rise to this river. And it is the common opinion, that this body of water, comes from the lake, through a subterraneous channel: which is the more probable, because the water of the lake and the river have the same qualities, and contain the very same sorts of fish, (being cold, hard, and remarkably unwholesome.)

Far different from this, is the water which rises out of the ground, throughout the vast sandy deserts of the Mongal Tartars. Wherever you dig, there rises fresh water. Were it not for this, they must have been altogether uninhabited, either by man or beast. It seems these springs are produced by the rains and melted snow in the spring. For the water sinking in the sand is thereby prevented from exhaling by the heat of the summer sun, which must be very scorching in these deserts, wherein there is not the least shade to be found.

Besides the rivers which run upon the surface of the earth, there are many which hide themselves

selves in its bowels, and run in subterraneous ducts, till they discharge themselves into the sea. A remarkable one of this kind has been discovered on the coast of Languedoc. There are also several of this sort on the coast of Croatia, over-against Venice.

Thus does the All-wise Creator shower down his treasures on the summits of the mountains, which afterwards diffuse their refreshing streams over the plains below, give life and verdure to the trees and herbs, and beautify and enrich the whole earth. At the same time we see the communication between those parts of nature, that before seemed to have no relation to each other. Indeed all nature is linked together by one law of harmony, which sufficiently proves it to be the work of one wise and gracious Author.

How delightful an object is a large and majestic River! How graceful an appearance does it make in the works of nature! Consider its progress. At first it is but a vein of water, streaming from some hill, and even the scattered pebbles interrupt its course, till it unites with other kindred streams, and then rushes on the plain below. By its fall it hollows the ground, casting it up on each side: then it pursues its course, eating a passage through every thing that opposes it. When it has received the supplies of many rivulets, it is dignified with a name. Thus enlarged, it makes the tour of hills and mountains, and at once adorns and enriches the plains.

At the deluge likewise the main Islands of the globe were formed. But it is certain others have been
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been formed in later ages: partly by the casting up of vast heaps of clay, mud and sand, (as that of Ifongming in the Chinese province of Nankin) partly by the violence of the sea, tearing off large provinces from the continent. So the ancients imagined Sicily to have been formed, and even Great Britain and Ireland. It is certain also, that others have emerged out of the sea, as Santorini formerly: and three other islands near it lately. The last of these rose in 1707, from the bottom of the sea, just after a violent earthquake. Indeed earthquakes, storms and inundations, have given rise to many islands: particularly in the East-Indies, where they are very frequent and which abounds in Islands above any part of the world.

12. The entire Bason of the Sea, is of such immense extent, and covered in many places with such an unfathomable depth of water, that it cannot be traced in every part: but from some, we may form a probable judgment of the rest. The materials which compose the bottom of the sea, must in a degree influence the taste of its waters. Its saltness it undoubtedly derives from mountains of salt which are found there: as bitterness from fossil coal and other bituminous substances, which are there in plenty. There may likewise be many other substances, which the plummet does not discover. For the true bottom of the sea is often concealed by another accidental bottom, formed of various substances, mingled together, and covering it to a considerable depth.

The entire gulph of Lyons forms a bank above the surface of the water at the shore, of the exact
figure

figure of an arch. And within this there is formed another such arch, making the bottom of the sea for a great way from shore, of different depths in various places, but generally between sixty and seventy fathoms. In general the bed of the main sea sinks about as high as the mountain rise on the land. Near the land in proportion to the height and steepness of the shores, the sea is deep below. And on the contrary level shores denote shallow seas.

By the strata on the shores we may commonly judge of the bottom of the adjacent seas. For the veins of salt and bitumen doubtless run in on the same order as we see them at land. And the strata of stone that serve to support the hills and elevated places on shore, serve also in the same continued chain, to support the waters of the sea. Probably the veins of metals and minerals likewise, which are found in the neighbouring earth, are in the same manner to be found in the bottom of the sea.

But the natural surface of the bottom of the sea, is greatly changed by subterranean currents. As we see these break out in rivers, on the surface of the earth, so we may be assured they break out at the bottom of the sea, and empty their fresh waters into the salt mass. In this case the continual rushing up of the water, makes a roundish cavity. And its running on, continues that cavity, 'till by degrees it is lost. Thus every river that arises in the bottom of the sea, when the water near the shore is clear, shews the traces of these currents, even to the naked eye, and the water taken up from them is more or less fresh.

Again. The coral fisheries give us occasion to observe, that there are many large caverns in the
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bottom of the sea, especially where it is rocky, as also in the sides of perpendicular rocks. These are often of great depth as well as extent, some with wide, others with narrow entrances. Nor is it any wonder, that as we daily find vast caverns on the land in rocky mountains, so we should find them in rocks under the sea. Nay, we may expect them in these the rather, as the rocks at land are in a state of rest, while those at sea are continually washed by the water, which insinuates every where, and by its continual agitation, enlarges every cavity it finds.

Upon the whole, it seems plain, that the basin of the sea was after the flood composed of the same substances, as the surface of the rest of the earth, namely, stone, clay, sand, and the like. It is true, the plummet in sounding usually brings up a matter composed of mud, dead weeds, broken shells, and various bodies cemented together by a sparry or tartareous substance. But these are only an artificial bottom, covering the natural one, such indeed as one might expect where numerous animals and vegetables are produced and decay, and where the quiet waters have time to deposit their stony matter, as our petrifying springs do.

There are places however where this adventitious crust is found, but the natural bottom appears of the same nature with the strata in the body of the earth. But the fine and pure sand we sometimes find, seems not to be the original bottom, but to have been rather brought into the sea by the course of some subterraneous river, and to be lodged in one of those particular basins, which these rivers form to themselves.

In deep water, where the surface only is disturbed by storms and the lower part remains more quiet for ages, the bottom is covered with a great variety of things: sometimes with pure sand, sometimes a sort of sand, made of shells beat to powder, sometimes with powdered corals, sometimes fragments of rocks. But beside these, which might well be expected, the plummet sometimes brings up substances, which are of the most beautiful colours: of as fine a scarlet, purple, or blue, as the finest paint could make them. Those of a bright yellow are very common; but the green or snow-white more rare. These coloured substances seem sometimes to make up the whole bottom. But they are more frequently found on other things, as upon mud, corals, or larger pieces of shells, in the manner of tartarous crusts. And their colours are not merely so superficial or transient, but many of them are so permanent, that they may be preserved in white wax, and when thus examined, they appear equal to paints of the finest kind.

There is very little difference between the bottom of the Adriatic Sea, and the surface of the neighbouring countries. There are at the bottom of the water, mountains, plains, valleys, and caverns, just as upon the land. The soil consists of different strata planted one upon another; and for the most part corresponds to those of the rock, islands, and neighbouring continents. They contain stones of different sorts, minerals, metals, various petrified bodies, pumice-stones, and lavas formed by volcanos. Istria, Dalmatia, Albania, and other adjacent countries, as well as the rocks, the islands, and the bottom of the Adriatic sea,

consist of a mass of white marble, of an uniform grain, and of almost an equal hardness. This vast bed of marble in many places under both the earth and the sea, is interrupted by several other kinds of marble, and covered by a great variety of bodies. The variety of these soils under the sea is remarkable: it is to this are owing the varieties of plants and animals found at the bottom of the sea. Some places are inhabited by a great number of different species of plants and animals, in others only some particular species are found, and in others neither plants nor animals. These observations not only point out to us the resemblance between the surface of the earth, and the bottom of the sea, but likewise one cause of the varieties, which are observed in the distribution of the marine fossils found in the earth.

In that vast mass of marble, which is common to the bottom of the Adriatic, and the neighbouring provinces toward the east, are a multitude of marine bodies petrified; some of which are so united to the stony substance, that they are scarce to be distinguished. Likewise a crust is discovered under the waters in divers places, and for a great extent, which is a composition of crustaceous and testaceous bodies, and beds of Polypi of different kinds, confusedly blended with earth, sand, and gravel.

These different bodies, which enter into the composition of this crust, are at the depth of a foot or more entirely petrified and reduced into marble. At less than the depth of a foot they approach nearer to their natural state. And at the surface of this crust, they are either dead, though extremely well preserved, or still living.

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This demonstrates that stones may be formed from things petrified, and actually are formed, in great quantities under the water. Crustaceous and testaceous bodies and Polypi, are every where mingled in the utmost confusion, which shews a striking resemblance between the crust discovered under the sea, and the marine bodies petrified in many parts under the earth.

The more these crustaceous and testaceous bodies and beds of Polypi multiply, the more their exuvia, and skeletons contribute to enlarge this crust. In several parts it forms very considerable banks, and of a very great thickness.

It follows that the bottom of the sea is rising constantly higher and higher. Divers other causes contribute to this; snow, and rain, and waters that bring down from the mountains, into the sea, a great quantity of earth and stones. The waves, beating against the continent and islands, detach many masses which are spread upon the bottom of the sea. The rivers carry the mud with their waters into the sea, at the bottom of which that mud deposits itself.

From the rising of the bottom of the sea, that of the level of the water naturally follows. So at Venice, in Istria, and in Dalmatia, the level of the waters is several feet higher than it was formerly. This elevation is observed only on the northern and eastern coasts of the Adriatic. The sea seems on the contrary, to abandon the western coast, that of Italy.

The eye can reach but a short way into the depth of any sea, and that only when the surface is glassy and serene. In many seas it perceives nothing but a bright sandy plain at bottom,

extending for several hundred miles. But in others, particularly in the Red Sea, it is very different: the whole bottom of this extensive bed of water, is a forest of submarine plants, and corals formed by insects for their habitation: sometimes branching out to a great extent; so that some have even supposed the sea to have taken its name from the colour of its plants below. However, these are not peculiar to this sea, as they are found in great quantities in the Persian gulf, along the coasts of Africa and those of Provence and Catalonia.

The bottom of many parts of the sea near America presents a very different appearance. This is covered with vegetables, which makes it look as green as a meadow; and beneath are seen thousands of turtles, and other sea animals feeding therein.

Ocean-shells are frequently found very near the surface, which proves that such places formerly have been the sea-shore. Hence it is clear, that the cause which transported them thither, acted suddenly, which perfectly agrees with the account of the deluge given by Moses.

Nay, at Touraine, in France, more than an hundred miles from the sea, there is a plain of about nine leagues long, and as many broad, from whence the peasants of the country supply themselves with marle. If they dig deeper than twenty feet, the whole plain is composed of the same materials, which are shells of various kinds, without the smallest portion of earth between them. These shells are in their natural state: but they are found also petrified and almost in equal abundance in all the Alfine rocks, in the Pyrennees, in the hills of France, England, and Flanders. Ye, ain all
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quarters from whence Marble is dug, if the rock be split perpendicularly down, petrified shells, and other marine substances will be plainly discerned. In several parts of Asia and Africa, travellers have observed these shells in great abundance. In the mountains of Castravan, they quarry out a white stone, every part of which contains petrified fishes in great numbers, and of surprizing diversity, in such preservation, that their fins, scales, and all the minutest distentions of their make can be perfectly discerned. From all these instances we may conclude that these fossils are very numerous. And the variety of their kinds is astonishing. Most of the sea-shells which are known, and many others to which we are entirely strangers, are to be seen either in their natural state, or in various degrees of petrification. But in the place of some we have more spar, or stone exactly expressing all the lineaments of animals: for the shells dissolving by slow degrees, and the matter having exactly filled all the cavities within, this matter retains the same form which the shells were of.

The greatest depths of the sea ever yet found, have been found to be about 3000 fathoms. The ordinary depths are about 150. Though these shells are to be found in almost all the plainer parts of the surface of the earth, yet there are certain very large tracts, where such bodies are never found, viz. the mountains, which seem to be the remains of the original strata of the earth. It is true that there are many eminences, which have been taken for mountains, where sea-shells of every kind are found: but these hillocks, compared with the large mountains, which may be traced in immense chains, without almost any discontinuity,

discontinuity, from one continent to another; and from continents to neighbouring and opposite islands; infomuch that all these chains not only of the old, but likewise of the new world seem connected one with another. In the Alps, Apennine and Pyreneans, no shells nor marine bodies of any kind are to be found: neither in the large Grampion mountains in Scotland.

The same is observed of all the large mountains of Africa, and of Asia, and in the huge chain of Cordilleres in Peru. This kind of mountains (which indeed alone deserve that name) are chiefly composed of vitrifiable matter; and if they are sometimes found to contain sea-shells, it is never to great depths, though such bodies are found in great abundance in the adjacent valleys.

Potters earth, is found plentifully in most low grounds and valleys, between mountainous tracts. By exposing common flint stones to the confined vapour of boiling water, a clay of the very same kind may be formed, and is no more than a decomposition of flints. Hence it appears that wherever this clay is to be found, there the earth has undergone some violence by fire; and that this has been effected by earthquakes, soon after the deluge, seems extremely probable. The deluge has given origin to many fossil substances, and combinations, which otherwise would not have happened. Chalk is no more than the ruins of sea-shells, and lime-stones consist of the same bodies cemented together by a stony juice.

13. At fixed times the water of the sea runs for near six hours from south to north, which is called the Flood, at which time it rises gradually on our shores,

shores, and in the channels of the rivers. Then after standing at the same height for a quarter of an hour, it returns for near six hours from north to south, which we term the Ebb; and after a quarter of an hour the water rises again. The change thereof is twice in twenty-four hours, but begins near fifty minutes later daily. And this is observed on all the shores of Europe, that are washed by the ocean: whereas the Baltic and Mediterranean sea, as well as the Caspian, have no tides. The nearer we approach the pole, the more impetuous the tides are. The cause of them was wholly concealed from the antients; but it is now well known to every one. They depend entirely on the motion of the moon, with which they exactly correspond: the flood beginning to rise just at the time when the moon is in the meridian.

There is something remarkable in the manner, wherein the tides rise, in several of our rivers. In the river Severn, in particular near Newnham, and 160 miles from Lundy, the head of the flood at spring-tides rise in height like a wall, near nine foot high. Thus it pours on for many miles, usually oversetting any vessels that lies in its way. This head-tide they call the Boar; it flows here only two, and ebbs ten hours.

But how shall we account for the ebbing and flowing of Lay-well, near Torbay? This ebbs and flows many times in an hour. It usually performs its flux- and reflux in a minute's time. But it stands two or three minutes after the ebb: so that in the whole it ebbs and flows about sixteen times in an hour.

14. Currents in the sea are either natural and general, arising from the daily rotation of the earth on its axis, or particular or accidental-caused by the waters being driven against promontories, or into gulphs and straits, where wanting room to spread, they are driven back, and so disturb the ordinary flux of the sea.

The currents are so violent near the line, where the motion of the earth is the greatest, that they carry vessels swiftly from Africa to America, but prevent their returning the same way. So that they run as far as the fortieth degree, to find a passage into Europe.

In the Straits of Gibraltar, which are about twenty miles broad, the current almost always runs eastward. And so it usually does in St. George's Channel. But the most violent sea is in the Straits of Magellan, which is owing to two contrary currents, which meet in those straits.

Sometimes there is an under-current, contrary to that above. So it is in the Baltic Sound. One of the king's frigates being there, they went with their pinnace in the mid stream, and were carried violently by the current. Soon after they sunk a basket with a large cannon-bullet to a certain depth of water. This checked the motion of the boat. And when they sunk it lower the boat was driven a head against the wind as well as the upper current. And the lower the basket was let down, the stronger the current was found. The upper current appeared by this experiment, not above four or five fathom deep.

And does not the following instance shew that there is an under current at the mouth of the Mediterranean sea? In the year 1712, Mons. l'Aigle, commander of a privateer, chasing a Dutch ship
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near Ceuta Point, came up with her in the Straits between Tariffa and Tangier, and giving her one broad-side sunk her. A few days after this ship with her cargo of brandy and oil arose near Tangier, four leagues west of that place, where she sunk, and directly against the strength of the current. Certainly then the deep water in the middle of the Strait, sets outward to the grand ocean. And possibly great part of the water, which runs in at the Straits, may run out again that way.

One of the most violent currents in the northern seas, runs between two of the western isles. The sea begins to boil with the tide of flood, and increases gradually, till there are many whirlpools, which form themselves into a sort of pyramids, and immediately spout out as high as the mast of a little vessel. At the same time they make a loud report. These white waves run two leagues before they break. The sea continues these motions, till it is more than half flood, and then decreases gradually, till it has ebbed half an hour. From that time it boils again, till it is within an hour of low-water. This boiling of the sea is about a pistol-shot distant from the isle of Scarba. But the smallest boat may safely cross the gulph, at the last hour of the flood or of the ebb.

In like manner, the collision of the opposite and oblique streams, near the end of the Orkney islands, excites a circular motion in the water, and when the swiftness of the tide is inconsiderable, occasions whirlpools or cavities in the sea, in the form of an inverted bell, wide at the mouth, and growing gradually narrower towards the bottom. Their width and depth are in proportion to the rapidity of the streams that cause them. Those in Pentland Firth, near the islands Storma and

Swona, will with a spring-tide, turn any vessel quite round. There have been instances of boats being swallowed up in them. The cavity is largest when it is first formed, and is carried along with the stream, diminishing gradually as it goes, until it quite disappears. The suction communicated to the water, does not extend farther than the cavity. When fishermen are aware of their approach to one of these Wells, as they call them; and have time to throw an ore or any other bulky body into it, before they are too near, the spiral motion is interrupted, and the continuity of the water broke, which rushing in on all sides, fills up the cavity, and enables them to go over it safe.

The Marlstroon, on the coast of Norway, as received from the natives, which signifies the Navel of the Sea, since they suppose a great share of the water of the sea is sucked up and discharged by its vortex. A description of the internal parts is not to be expected, since none ever returned thence to bring information. The body of waters that form this whirlpool are extended in a circle about thirteen miles in circumference. In the midst of this stands a rock, against which the tide in its ebb is dashed with inconceivable fury. At this time it instantly swallows up all things that come within the sphere of its violence, trees, timber, and shipping. No skill in the mariners, nor strength in rowing, can work an escape: the sailor at the helm finds the ship first go in a current opposite to his intentions: his vessel's motion, though slow in the beginning, becomes every moment more rapid; and it goes round in circles still narrower and narrower, till

at least it is dashed against the rocks, and instantly disappears: nor is it seen again for six hours; till the tide turning, it is vomitted forth with the same violence with which it was drawn in. The noise of this vortex increases its terror, which with the dashing of the waters, and the dreadful valley covered by their circulation, makes one of the most tremendous objects in nature.

May I be permitted to mention here, a cheap and easy way of making sea-water fresh, "I took, says a gentleman, a long glass body, and having filled it with sea-water, put therein sea-weed with its roots fresh and new gathered. Then I put on a head and a beak, and adapted a receiver thereto, without any lute or closing the joints. From the plants distilled daily, a small quantity of very sweet and potable water. And probably there may be found other plants near the sea, which would yield fresh water in large quantities.

Sea-water simply distilled affords a water as pure and wholesome, as that obtained from the best springs.

From the improvements made by Dr. Hales, it appears that three quarts of water might be procured in five minutes, that is fifty gallons in twelve hours, from a small cylindrical still of Mr. Durand's, by setting some pewter plates edge-ways in its head. And a still thirty-two inches diameter would give two hundred gallons in twelve hours, with only the expence of a bushel and half of coals.

When sea-water is boiled in a close covered vessel, the steam is converted into fresh-water on the

the inside of the cover. And from a pot of thirteen inches diameter, by frequently removing the cover, and pouring off the water collected upon it, a quarter of a pint of fresh water in an hour.

Perhaps yet a better way of making sea-water fresh is the following. Take bees wax, and mould it into the form of an empty hollow vessel; sink the vessel into the sea. The water, in some will work its way through the pores of the wax, and the quantity contained in the vessel will be fresh, and good for use. The same will happen by using a rude earthen vessel, and stopping the aperture: for the water that penetrates is percolated and pure.

But fresh-water may be had in much greater plenty, and more expeditiously, by filling a vessel with river-sand or gravel, and pouring salt-water upon it. The vessel must be perforated at bottom, and by applying a linen strainer the water, after under going a few filtrations, will lose all its brackish taste.

In order to keep fresh-water sweet, take of fine clear, white, pearl ashes, a quarter of a pound of avoirdupoise, and put into one hundred gallons of fresh-water (observing this proportion to a greater or lesser quantity) and stop up your cask as usual till you have occasion to broach it for use. As an instance of its utility and success, Dr. Butler put an ounce of pearl ashes into a twenty-five gallon cask of Thames water, which he stopt up very close, and let it stand for upwards of a year and a half, opening it once in four months, and constantly found in it the same unaltered condition and perfectly sweet and good: afterwards made use of some of it in boiling pease and burgoo, and found that it
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made the pease as soft, and answered for all purposes to which he applied it, as well as water fresh drawn out of the river.

To this short sketch of what is observable in the terraqueous globe, I subjoin some of the beautiful reflections of Mr. Hervey.

“ What an admirable specimen have we here, of the Divine skill and goodness? This globe is intended, not only for an habitation, but for a storehouse of conveniences. And if we examine the several apartments of our great abode, we shall find reason to be charmed with the displays both of nice œconomy and boundless profusion.

The Surface of it, the ground, coarse as it may seem, is yet the Laboratory where the most exquisite operations are performed. And though a multitude of generations have been accommodated by it, it still continues inexhaustible.

The Unevenness of the ground, far from being a defect, heightens its beauty and augments its usefulness. Here it is scooped into deep and sheltered vales, almost constantly covered with verdure, which yields an easy couch and agreeable food to the various tribes of cattle. There it extends into a wide, open country, which annually bears a copious harvest: an harvest not only of the principal Wheat, which is the staff of our life, but of the appointed Barley, and various other grain, which are food for our animals.

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The Furrows vary their produce. They bring forth Flax and Hemp, which help us to some of the most necessary accommodations of life. These are wove into ample volumes of cloth, which fixed to the mast, give wings to our ships. It is twisted into vast lengths of cordage, which give nerves to the crane, and sinews to the pully, or else adhering to the anchor, secure the vessel, even amidst the driving tempest. It covers our tables with a graceful elegance, and surrounds our bodies with a cherishing warmth.

Yonder arise the hills, like a grand Amphitheatre! Some are clad with mantling vines, some crowned with towering cedars, some ragged with mis-shapen rocks, or yawning with subterraneous caves. And even those inaccessible craggs, those gloomy cavities, are not only *a refuge for wild goats*, but sometimes for *those of whom the world was not worthy*.

At a greater distance the mountains penetrate the clouds, with their aspiring brows. Their sides *arrest* and *condense* the vapours as they float along. Their caverned bowels *collect* the dripping treasures, and send them gradually abroad by trickling springs: and hence the waters increasing roll down, till they have swept through the most extensive climes, and regained their native seas.

The Vine requires a strong reflection of the sunbeams and a large proportion of warmth. How commodiously do the hills and mountains minister to this purpose? May we not call those vast declivities the garden-walls of nature? These con-

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center the solar fire, and completely ripen the grape! O that any should turn so valuable a gift of God into an instrument of sin!

What is nature but a series of wonders? That such a variety of fruits should rise from the insipid fordid earth? I take a walk through my garden or orchard in December. There stand several logs of wood on the ground. They have neither sense nor motion; yet in a little time they are beautified with blossoms, they are covered with leaves, and at last loaded with fruit. I have wondered at the account of those prodigious engines, invented by Archimedes. But what are all the inventions of men, to those nice automata of nature?

The Forest rears myriads of massy bodies, which though neither gay with blossoms, nor rich with fruit, supply us with timber of various kinds. But who shall cultivate them? The toil were endless. See therefore the ever wise and gracious ordination of Providence! They have no need of the spade or the pruning-knife. They want no help from man.

When sawed into beams they sustain the roofs of our houses. They make carriages to convey our heaviest loads. Their substance is so pliant, that they are easily formed into every kind of furniture: yet their texture so solid, that they compose the most important parts of the largest engines. At the same time, their pressure is so light, that they float upon the waters. Thus while they serve all the ends of architecture, and bestow numberless conveniences on the family, they constitute

stitute the very basis of navigation; and give being to commerce.

If we descend from the Ground Floor of our habitation into the subterraneous lodgments, we shall find there also the most exquisite contrivance acting in concert with the most profuse goodness. Here are various *minerals* of sovereign efficacy: beds fraught with *metals* of richest value: and mines, which yield a metal of a meaner aspect, but superior usefulness. Without the assistance of iron, what would become of all our mechanic skill? without this we could scarce either fix the mast, or drop the faithful anchor. We should scarce have any ornament for polite, or utensil for common life.

Here is an inexhaustible fund of combustible materials. These mollify the most stubborn bars. They melt even the most stubborn flint, and make it more ductile than the softest clay. By this means we are furnished with the most curious and serviceable manufacture in the world; which admits into our houses the chearing light, yet excludes the wind and rain: which gives new eyes to decrepit age, and more enlarged views to philosophy; bringing near what is immensely remote, and making visible what is immensely small.

Here are quarries stocked with stones, which do not sparkle like gems, but are more eminently useful. These form houses for peace, fortifications for war. These constitute the arches of the bridge, the arms of the mole or quay, which screen our ships from the most tempestuous seas.

These

These are comparatively soft in the bowels of the earth, but harden when in the open air. Was this remarkable peculiarity reversed, what difficulties would attend the labours of the mason? His materials could not be extracted from their bed, nor fashioned without infinite toil. And were his work completed, it could not long withstand the fury of the elements.

Here are various assortments and beds of Clay, which however contemptible in its appearance, is abundantly more beneficial than the rocks of diamond or veins of gold: this is moulded into vessels of any shape and size: some so delicately fine as to suit the table of a princess; others so remarkably cheap, that they minister to the convenience of the poorest peasant: all so perfectly neat, as to give no disgust even to the nicest palate.

A multiplicity of other valuable stores is locked up in these ample vaults. But the key of all is given to industry, in order to produce each as necessity demands.

Which shall we most admire, the bounty or wisdom of our great Creator? How admirable is his precaution in removing these cumbrous wares from the surface, and bestowing them under the ground in proper repositories? Were they scattered over the surface of the soil, it would be embarrassed with the enormous load. Our roads would be blocked up, and scarce any room left for the operations of husbandry. Were they on the other hand, buried at a great depth, it would cost us immense pains to procure them. Were they

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they uniformly spread into a pavement for nature, universal barrenness must ensue: whereas at present we have a magazine of metallic, without lessening our vegetable treasures. Fossils of every kind enrich the bowels, verdure adorns the face of the earth.

Well then may even the inhabitants of heaven lift up their voice and sing, *Great and marvellous are thy works, O Lord God Almighty!* And is there not infinite reason for us to join this triumphant choir? Since all these things are to us, not only a noble spectacle, bright with the display of our Creator's wisdom, but likewise an inestimable gift, rich with the emanations of his goodness? *The earth hath he set before the inhabitants of his glory: but he hath given it to the children of men.* Has he not then an undoubted right to make that tender demand, "*My son, give me thine heart!*"

The Rocks which bound the sea, are here prodigiously high and strong, an everlasting barrier against both winds and waves. Not that the Omnipotent engineer has any need of these here. It is true, they intervene, and not only repress the rolling billows, but speak the amazing Majesty of the Maker. But in other places the Creator shews, he is confined to no expedient. He bids a bank of despicable sand repel the most furious shocks of assaulting seas. And though the waves toss themselves, they cannot prevail: though they roar, yet they cannot pass over.

Nay, is it not remarkable, that Sand is a more effectual barrier against the sea than Rock? Accordingly

cordingly the sea is continually gaining upon a rocky shore: but it is continually losing on a sandy shore, unless where it sets in with an eddie. Thus it has been gaining from age to age, upon the isle of Portland and the Land's End in Cornwall, undermining, throwing down, and swallowing up one huge rock after another. Meantime the sandy shores both on our southern and western coasts, gain continually upon the sea.

Beneath the Rocks frequently lies a smooth, level sand, almost as firm as a well-compacted causeway: insomuch that the tread of an horse scarce impresses it, and the waters never penetrate it. Without this wise contrivance the searching waves would insinuate into the heart of the earth; and the earth itself would in some places be hollow as an honey-comb, in others bibulous as a sponge. But this closely-cemented pavement is like claying the bottom of the universal canal: so that the returning tides only consolidate its substance, and prevent the sun from cleaving it with chinks.

Here the Main rolls its surges from world to world. What a spectacle of magnificence and terror! How it fills the mind and amazes the imagination! It is the most august object under the whole heaven. What are all the canals on earth, to this immense reservoir? What are the proudest palaces on earth, to yonder concave of the skies? What the most pompous illuminations, to this source of day? They are a spark, an atom, a drop. Nay in every spark and atom and drop, that proceeds from the hand of the Almighty,

mighty, there is the manifestation of a wisdom and a power absolutely incomprehensible.

Let us examine a single drop of water, only so much as will adhere to the point of a needle. In this speck an eminent philosopher computes no less than thirteen thousand globules. And if so many thousands exist in so small a speck, how many in the unmeasured extent of the ocean? Who can count them? As well may we grasp the wind in our fist, or mete out the universe with our span.

Nor are these regions without their proper inhabitants, clothed in exact conformity to the clime: not in swelling wool, or buoyant feathers, but with as much compactness and as little superfluity as possible. They are clad, or rather sheathed in Scales, which adhere close, and are laid in a kind of natural oil: than which apparel nothing can be more light, and at the same time nothing more solid. It hinders the fluid from penetrating their flesh: it prevents the cold from chilling their blood; and enables them to make their way through the waters, with the utmost facility. And they have each an air-bladder, a curious instrument, by which they rise to what height, or sink to what depth they please.

It is impossible to enumerate the scaly herds. Here are animals of monstrous shapes, and amazing qualities. The upper jaw of the Sword-fish is lengthened into a strong and sharp sword, with which (though not above sixteen feet long) he scruples not to engage the Whale himself. The Sun-

Sun-fish is one round mass of flesh; only it has two fins, which act the part of oars. The Polypus, with its numerous feet and claws, seems fitted only to crawl. Yet an excrescence rising on the back enables it to steer a steady course in the waves. The shell of the Nautilus forms a kind of boat, and he unfurls a membrane to the wind for a sail. He extends also two arms, with which as with oars, he rows himself along. When he is disposed to dive, he strikes sail, and at once sinks to the bottom. When the weather is calm he mounts again, and performs his voyage without either chart or compass.

Here are sholes upon sholes of every size and form. Some lodged in their shells, seem to have no higher employ, than imbibing nutriment, and are almost rooted to the rocks on which they lie: while others shoot along the yielding flood, and range the spacious regions of the deep. How various is their figure! The shells of some seem to be the rude production of chance, rather than of skill or design. Yet even in these we find the nicest dispositions. Uncouth as they are, they are exactly suited to the exigencies of their respective tenants. Some on the other hand are extremely neat. Their structure is all symmetry and elegance. No enamel is comparable to their polish. Not a room in all the palaces of Europe is so adorned as the bedchamber of the little fish that dwells in mother of Pearl. Where else is such a mixture of red, blue and green, so delightfully staining the most clear and glistering ground?

But what I admire more than all their beauty, is the provision made for their Safety. As they
have

have no speed to escape, so they have no dexterity to elude their foe. So that were they naked, they must be an easy prey to every free-booter. To prevent this, what is only cloathing to other animals, is to them a cloathing, an house, and a castle. They have a fortification which grows with them, and is a part of themselves. And by means of this they live secure amidst millions of ravenous jaws.

Here dwell Mackrel, Herring, and various other kinds, which when lean wander up and down the ocean : but when fat they throng our creeks and bays, or haunt the running streams. Who bids these creatures leave our shores when they become unfit for our service ? Who rallies and recalls the undisciplined vagrants, as soon as they are improved into desirable food ? Surely the furrow is signed, the summons issued, and the point of re-union settled, by a Providence ever indulgent to mankind, ever loading us with benefits.

These approach, while those of enormous size and appearance abandon our shores. The latter would fright the valuable fish from our coasts ; they are therefore kept in the abysses of the ocean : just as wild beasts, impelled by the same over-ruling power, hide themselves in the recesses of the forest.

One circumstance relating to the natives of the deep is very astonishing. As they are continually obliged to devour one another for necessary subsistence, without extraordinary recruits, the whole watery race must soon be totally extinct. Were they

they to bring forth no more at a birth than land animals, the increase would be far too small for the consumption. The weaker species would soon be destroyed by the stronger, and the stronger themselves must soon after perish. Therefore to supply millions of animals with their food, and yet not depopulate the watery realms, the issue produced by every breeder is almost incredible. They spawn not by scores, but by millions: a single female is pregnant with a nation. Mr. Lewenhoeck counted in an ordinary cod 9,384,000 eggs. By this amazing expedient, constant reparation is made, proportionable to the immense havock.

And as the sea abounds with animal inhabitants, so it does also with vegetable productions: some soft as wool, others hard as stone. Some rise like a leafless shrub, some are expanded in the form of a net: some grow with their heads downward, and seem rather hanging on, than springing from the juttings of the rocks. But as we know few particulars concerning these, I would only offer one remark in general. The herbs and trees on the dry land are fed by the juices that permeate the soil, and fluctuate in the air. For this purpose they are furnished with leaves to collect the one, and with roots to attract the other. Whereas the sea-plants, having sufficient nourishment in the circumambient waters, have no need to detach roots into the ground, or forage the earth for sustenance. Instead therefore of penetrating, they are but just tacked to the bottom, and adhere to some solid substance only with such a degree of tenacity, as may secure them from being tost to and fro by the agitation of the waves.

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We see from this and numberless other instances, what diversity there is in the operations of the great Creator. Yet every alteration is an improvement, and each new pattern has a peculiar fitness of its own.

Considered in another view, the sea is that grand Reservoir, which supplies the earth with its fertility: and the air and sun are the mighty engines, which work without intermission, to raise the water from this inexhaustible cistern. The clouds as aqueducts convey the genial stores along the atmosphere, and distribute them in seasonable and regular proportions, through all the regions of the globe.

How hardly do we extract a drop of perfectly sweet water from this vast pit of brine? Yet the sun draws off every moment millions of tons in vaporous exhalations, which being securely lodged in the Bottles of Heaven, are sent abroad sweetened and refined, without the least brackish tincture, or bituminous sediment: sent abroad upon the wings of the wind, to distil in dews and rain, to ooze in fountains, to trickle along in rivulets to roll from the sides of mountains, to flow in copious streams amidst burning deserts and through populous kingdoms, in order to refresh and fertilize, to beautify and enrich every soil in every clime.

How amiable is the goodness, how amazing the power, of the world's adorable Maker! How amiable his goodness, in distributing so largely what is so extensively beneficial? That water, without which we can scarce perform any business, or enjoy any comfort, should stream by our houses, start up from the ground, drop down from the clouds. Should come from the ends of the earth, to serve

us, from the extremities of the ocean! How amazing his power! That this boundless mass of fluid salt, so intolerably nauseous to the taste, should be the original spring, which quenches the thirst both of man and every animal! Doubtless the power by which this is effected, can make *all things work together for our good.*

Vast and various are the advantages which we receive from this liquid element. The waters glide on in spacious currents, which not only clear the adjacent country, but by giving a brisk motion to the air, prevent the stagnation of the vapours. They pass by large cities, and quietly rid them of a thousand nuisances. But they are also fit for more honourable services. They enter the gardens of a prince, float in the canal, ascend in the Jet d'Eau, or fall in the grand cascade. In another kind they ply at our mills, toil incessantly at the wheel, and by working the largest engines, take upon them an unknown share of our fatigue, and save us both labour, time, and expence.

So forcibly do they act when collected. And how do they insinuate when detached? They penetrate the minutest tubes of a plant, and find a passage through all its meanders. With how much difficulty does the labourer push his way up the rounds of a ladder? While these carry their load to a much greater height, and climb with the utmost ease. They convey nourishment from the lowest fibres that are plunged in the earth, to the topmost twigs that wave amidst the clouds. Thus they furnish the whole vegetable world with necessary provision, by means of which *the trees of the Lord are full of sap, even the cedars of Lebanon, which he hath planted.* And notwithstanding their vast elevation and prodigious dis-

fusion, not a single branch is destitute of leaves, nor a single leaf of moisture.

Besides the salutary and useful circulation of the rivers, the sea has a motion no less advantageous. Daily for five or six hours, it flows toward the land, and for the same time, retires to its inmost caverns. How great is the power that protrudes to the shores such an inconceivable weight of waters, without any concurrence from the winds, often in direct opposition to them? Which bids the mighty element revolve with the most exact punctuality? Did it advance with a lawless and unlimited swell, it might deluge whole continents. Was it irregular and uncertain in its approaches, navigation would be at a stand. But being constant in its stated period, and never exceeding its appointed bounds, it does no prejudice to the country, and serves all the ends of traffic.

Is the sailor returned from his voyage? The Flux is ready to convey his vessel to the very doors of the owner, without any hazard of striking on the rocks, or of being fastened in the sands. Has the merchant freighted his ship? The Reflux bears it away with the utmost expedition and safety. Behold, O man, how highly thou art favoured by thy Maker! *He hath put all things in subjection under thy feet. All sheep and oxen, all the beasts of the field: the fowls of the air, and the fishes of the sea.* Yea, the surges of the sea are subservient to thee. Even these, wild and impetuous as they are, are ready to receive thy load, and like an indefatigable beast of burden, carry it to the place which thou chooseth.

What preserves this vast flood in perpetual purity? It receives the refuse and filth of the whole world. Whatever would defile the land and pol-
lute

lute the air, is transmitted to the ocean. How then this receptacle of every nuisance kept clean, kept is from contracting a noisome and pestilential taint? 'tis partly by its incessant motion, and partly by its saltness. By the one it is secured from any internal principle of corruption; by the other it works itself clear of any adventitious defilement.

Consider the sea in another capacity, and it connects the remotest realms of the universe, by facilitating the intercourse, between their respective inhabitants. The antients indeed looked on the ocean, as an impassable gulph. But we find it just the reverse; not a bar of separation, but the great bond of union. For this purpose it is never exhausted, though it supplies the whole earth with rain: nor overflows, though all the rivers in the universe are perpetually augmenting its stores. By means of this we travel farther, than birds of the strongest pinions fly. We cross the flaming line, visit the frozen pole, and wing our way even round the globe.

What a multitude of ships are continually passing and repassing this universal thorough-fair! Whole harvests of corn, and vintages of wine, lodged in volatile store-houses, are waisted by the breath of heaven, to the very ends of the earth: waisted, enormous and unweildy as they are, almost as speedily as the roe bounds over the hills.

Astonishing, that an element so unstable, should bear so immense a weight! That the thin air should drive on with such speed those vast bodies, which the strength of a legion could scarce move! That the air and water should carry to the distance of many thousand miles, what the united force of men and machines could scarce drag a single yard!

yard! *Great and marvellous are thy works, O Lord God Almighty!*

How are the mariners conducted through this fluid common, than which nothing is more wide or more wild? Here is no tract, no posts of direction, nor any hut where the traveller may ask his way. Are they guided by a pillar of fire? No, but by a mean, and otherwise worthless fossil. Till this surprising stone was discovered, ships crept timorously along the coasts. But this guides them, when nothing but skies are seen above, and nothing but seas below. This gives intelligence that shines clear in the thickest darkness, and remains steady in the most tempestuous agitations. This emboldens us to launch into the heart of the ocean, and to range from pole to pole.

By this means are imported to our islands the choice productions of every nation under heaven. Every tide conveys into our ports, the treasures of the remotest climes. And almost every private house in the kingdom, is accommodated from the four quarters of the globe. At the same time that the sea adorns the abodes of the rich, it employs the hands of the poor. What a multitude of people acquire a livelihood, by preparing commodities for exportation? And what a multitude by manufacturing the wares imported from abroad? Thus though it is a false supposition, that the waters themselves are strained through subterranean passages into the inland countries, yet it is true, that their effects are transfused into every town, every hamlet and every cottage."

I beg leave to insert here what could not properly come in under any of the preceding articles.

It is a curious remark, which Dr. Cheyne makes concerning

concerning fluids in general. " I take notice, first of the fewness of the original fluids, in respect first of the vast number of compound ones. The primary ones hitherto known are only four, air, water, mercury, and light, three of which are seldom much compounded with others; so that it is water alone, that is the basis of all our mixtures. It is the parts of solid bodies floating in this fluid, that produce all our delightful and useful varieties of liquors: so frugal is nature in principles, and so fruitful in effects and compositions. Take notice, 2dly, Of the great difference between the specific gravities of our fluids, mercury being eight thousand times heavier than air. Now not to mention the many uses of this last fluid in artificers works, had air been as heavy as mercury it had been altogether useless in respiration: it had choaked us immediately. And had there not been a fluid of the same weight with mercury, i. e. a collection of exceeding small, heavy spherules in the present circumstances of mankind, I do not know what a great part of the world would have done. For the wickedness of mankind, has brought many diseases to that degree of malignity, that a thorough cure could scarce be made of them without this fluid. But by the gravity of this, a remedy is provided for all these maladies, which are more than two or three. But that which is most wonderful in these fluids is, 3dly, That universal property, the direction of their pressure upon the sides of the containing vessel. In all fluids of whatsoever kind or nature this pressure is communicated in lines perpendicular to the sides of the containing vessel. And indeed this property of fluids, which is so uniform, is the necessary consequence of the sphericity of their constituent particles.

Now, could any thing but the almighty power of God, have rounded those infinite numbers of small particles? Or could any thing but his wisdom have assigned them their true dimensions, their exact weights, and required solidities? We shall allow him to continue in his infidelity, who can demonstrate by what laws of mechanism, all the particles of water were turned of the same diameter solidity, and weight; and those of air, mercury, and light turned all of different diameters, solidities, and weights from one another; but all of the same diameters, solidities, and weights among themselves. And what a beautiful idea of this fluid does Sir Isaac Newton's later discoveries present us with; every ray is endowed with its own colour, and its different degree of refrangibility and reflexibility. One ray is violet, another indigo, a third blue, a fourth green, a fifth yellow, a sixth orange, and the last red. And these are the primary and original colours from the mixture whereof all the intermediate ones proceed; and white from an equal mixture of the whole; black on the contrary, from the small quantity of any of them being reflected; or all of them in a great measure suffocated. So that it is not properly bodies that are coloured, but the light that falls upon them; and their colours arise from their aptitude, to reflect rays of one colour, and transmit all those of another. The prominent little parts, upon their surface, according to their different degree of density and thinness, are apt to reflect back upon our organ rays of one colour, and of one degree of refrangibility and reflexibility, and to let others pass through their pores, and this one colour too is less or more intense, according as their prominent parts are of different

different densities. For the first degrees of intenseness, in all the primary colours, seem to arise from the degrees of density and thinness, and the subsequent degrees, from the other different degrees of thickness, or thinness of the prominent little parts of the surfaces of bodies. Light acts upon bodies by heating, dissolving, and putting their parts in a vibrating motion. Bodies act upon light, in drawing its parts to them, and that in lines perpendicular to their surfaces. And as there may be different degrees of attraction in bodies, which produce their different degrees of elasticity and cohesion, so there must be different degrees of attraction in mediums supposed, to account for their different powers, in bringing the refracted rays nearer to, or farther from the perpendicular. For it is well known all mediums have not the same refractive virtue. Now what a beautiful, uniform, and simple theory of light is here! This is so very like the frugal simplicity and yet the manifold variety of nature, that one would be almost tempted to believe it true, were there no experiment to confirm it. We may observe one more instance of the wonderful wisdom of nature, in the propagation of light, viz. That a ray of light in passing from a luminous point, through two differently refracting mediums, to illuminate a given point, spends the least time (the refracting powers of the several mediums considered) possible; and consequently when a ray passes through one medium, from a luminous point to reflect upon a given point, it takes the shortest way possible. This the Geometers have demonstrated. Now is not this an instance of council and design? Is not this like the methods of wisdom, which will not spend more time on a thing than just what is necessary to do the business;

which will not go about but take the shortest course possible that will bring it to the place designed ?

The islands of Scilly have been so noted among the antients, one might expect to find among the inhabitants some consciousness of their own antiquity, and of their appearance in history before the other parts of Britain were at all known. But there is nothing of this kind ; the inhabitants are all new comers, not an old habitation worth notice, nor any remains of Phœnecian, Grecian, or Roman arts, either in town, castle, port, temple, or sculpture.

We are not to think however but Scilly was inhabited, and was frequently resorted to antiently, as the old historians relate. All the islands (several of which are now without inhabitants) by the remains of walls, foundations of many contiguous houses, and a great number of sepulchral burrows, shew, that they have been fully cultivated and inhabited.

That they were inhabited by Britons, is past all doubt, not only from their neighbourhood to England, but from the Druid monuments. Several rude stone pillars, circles of stone erect, rock-basins: all monuments common in Cornwall and Wales, are equal evidences of the antiquity, religion, and original of the old inhabitants.

How came these antient inhabitants then (it may be asked) to vanish, so as that the present have no pretensions of any affinity of any kind with them, either in blood, language, or customs ? How came they to disappear, and leave so few traces of plenty, or arts, and no posterity behind them ? From two causes, the manifest encroachments of the sea, and as manifest a subsidence of some parts of the land.

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The sea is the insatiable monster which devours islands, gorges itself with the earth, sand, clay, and all the yielding parts, and leaves nothing where it can reach, but the skeleton, the bared rock. The continual advances, which the sea makes upon the low lands, are plain to all people of observation. What we see happening every day may assure us of what has happened in former times; and from the banks of sand and earth giving way to the sea, and the breaches becoming still more open, and irrecoverable: it appears, that repeated tempests have occasioned a gradual dissolution of the solids for many ages.

Again, the flats which stretch from one island to the other, are plain evidences of a former union between many now distinct islands. The flats between some of them are quite dry at a spring-tide, and men easily pass dry shod from one island to the other, over sand-banks where, upon the shifting the sands, walls and ruins are discovered frequently upon which at full sea there are ten and twelve feet of water.

All strong arguments that these islands were once one continued tract of land, though now as to their low lands over-run with the sea and sand. History confirms their former union "The isles Cassiterides (says Strabo) are ten in number, close to one another; one of them is desert and unpeopled, the rest are inhabited." But see how the sea has multiplied these islands! There are now reckoned one hundred and forty. Into so many fragments are they divided, and yet there are left six inhabited. But no circumstance can shew the great alterations, which have happened in the number and extent of these islands, more than this, viz. that the isle of Scilly, from which the

little cluster takes its name, is no more at present than a high rock, of about a furlong over, whose cliffs hardly any thing but birds can mount, and whose barrenness could never suffer any thing but sea-birds to inhabit it. How then came all these islands to have their general name from such a small and useless plot?

Doubtless Scilly, which is now a bare rock, and separate from the lands of Guel and Brehar by a narrow frith, was formerly joined to them by low necks of lands, being the rocky promontory of one large island now broke into seven. This promontory (at present called Scilly island) lying westernmost of all the high lands, was the first land of all the islands discerned by the traders from the Mediterranean and Spanish coasts, and, as soon as discovered was said to be Scilly, nothing being more usual with sailors, upon their first seeing land, than to call the part by the name of the whole. But when this considerable island called Scilly was broken to pieces, the greatest portions became inhabited, and had first British names, as Brehar, Trescaw, Enmor; but afterwards were called according to the religion of the times, after the names of particular saints. The chief division was intitled St. Mary's, the others dedicated to St. Nicholas, St. Martin, St. Theon, and so on; but this remarkable promontory being in no wise fit for habitation or devotion, was dedicated to no saint, but left to enjoy its ancient name; and notwithstanding the modern Christian dedications, sailors went on in their old way. This high land is still called Scilly, and the islands in general are still denominated Scilly isles.

It must have been a dispiriting circumstance to the old inhabitants, to see the ocean so continually
eating

eating away their low-lands, in which they had their treasures of tin, their houses and ports: but this gradual decay was not the only misfortune which attended them. From the island of Sampson, one may see the foundations of stone-fences running on in a strait line cross the Firth, towards Trescaw isle, till they are hid in the sand; which sand, when it is full tide, has from ten to twelve feet water on it. Now we cannot suppose that the foundation of these fences was laid as low as high water mark, (for who could build fences upon so dangerous a level?) At a medium we may suppose them to have been laid six feet above the full tide.

Here then we have the foundations, which were six feet above the high-water mark, now ten feet under, which together make a difference as to the level of sixteen feet.

Here then was a great subsidence, which must have been followed by a sudden inundation, and this inundation is likely not only to have destroyed a great part of the inhabitants, but to have terrified others who survived into a total desertion of their shattered islands. By this means that considerable people, who were the Aborigines, and carried on the tin trade with the Phœnecians, Greeks, and Romans, were reduced to the last gasp. The few poor remains of this desolation by their necessary attention to food and raiment, must soon have lost sight of their ancient prosperity, and the faint remembrance that was left of what the islands had been before, expired of itself in an age or two, through the indigence of the inhabitants.

That such an inundation has happened here, is still more plain, because these islands are no longer

what they were antiently, fertile in tin : nor are there any remains of so many antient workings as could maintain a trade so greedily coveted by the antients. But what is become of those mines ? How shall this question be answered, but by confessing that the land, in which they were, is now sunk, and buried under the sea ?

I am not fond of introducing earthquakes ; but where there has been evidently a great subsidence of the earth's surface, can it be accounted for at all without a previous concussion of the earth ? And what nature declares in this case, tradition seems to confirm ; there being a strong persuasion in the Western parts of Cornwall, that formerly there existed a large country between the Land's-End and Scilly, now laid many fathoms under water. Indeed there are no evidences of any ancient connexion of the Land's-End and Scilly. Yet that the cause of that inundation, which destroyed much of these islands, might reach also to the Cornish shores, is extremely probable ; there being several evidences of a like subsidence of the land in Mount's-Bay. The principal anchoring-place, called a lake, is now a haven or open harbour. The mount from its Cornish name, we must conclude to have stood formerly in a wood ; but now at full tide, it is half a mile in the sea, and not a tree near it ; and in the sandy beach betwixt the Mount and Penzance, when the sands have been dispersed by violent high tides, there have been seen the trunks of several large trees in their natural position, the surface of their section worn smooth by the agitation of the water, sand, and gravel, as if cut with an axe, upon which at every full tide, there must be twelve feet water ; so that the shores in Scilly, and the neighbouring shores
of

of Cornwall are concurrent evidences of such a subsidence, and the memory of the inundations, which were the necessary consequences of it, is preserved in tradition : though like other traditions, in proportion to their age, obscured by fable.

That there has been such a subsidence of the lands, belonging to these islands, the present ruins of the islands testify. And this subsidence reached even to Mount's Bay, and laid under water a great part of the low-lands then woody, there being now ten feet water, so that the shores in Scilly and the shores in Cornwall, are equal proofs of such an inundation. When this inundation happened, we know not ; but two pieces of history possibly may lead us near the time. In the time of Strabo and Diodorus Siculus, their commerce was in full vigour. " Abundance of tin was carried in carts, say Diodorus Siculus." " But ten islands in all (says Strabo) and nine of those inhabited." The destruction therefore of Scilly must be placed after the time of these authors ; that is, after the Augustan age.

Now Plutarch hints, that the islands round Britain were generally unpeopled in his time. If he includes Scilly among them, then this desolation must have happened between the reign of Trajan, and that of Augustus.

15. At the mouth of the river Nefs, near Burges, in Flanders, at the depth of fifty feet, are found great quantities of trees lying as close to each other, as they do in a wood ; the trunks, the branches, and the leaves are in such perfect preservation, that the particular kind of each tree may be known. About five hundred years ago this very ground was known to have been covered
ed

ed with the sea; nor is there any history of its having been dry ground, which no doubt must have been the case. Thus we see a country flourishing in verdure, producing large torrents, and trees of various kinds, overwhelmed by the sea. We see this element depositing its sediment to an height of fifty feet; and its waters must, therefore have risen much higher. We see the same after it has thus overwhelmed, and sunk the land so deep beneath its slime, capriciously retiring from the same coasts, and leaving it habitable once more. All this is wonderful, and perhaps instead of attempting to enquire after the cause, it will best become us to rest satisfied with admiration.

At the city of Modena in Italy, and about four miles round it, whenever they dig, when the workmen arrive at the depth of sixty-three feet, they come to a bed of chaulk, which they bore with an augre five feet deep. They then withdraw from the pit, before the augre is removed, and upon its extraction, the waters burst up through the aperture with great violence. That which is most remarkable in the operation is the layers of earth, as we descend. At the depth of fourteen feet are found the ruins of an ancient city, paved streets, houses, floors, and different pieces of Mosaic. Under this is found a solid earth, that one would imagine had never been removed; however, under it is found a soft oozy earth, made up of vegetables; and at twenty-six feet deep, large trees entire, such as walnut-trees, with the walnuts still sticking on the stem, and their leaves and branches in exact preservation. At twenty-eight feet deeper a soft chalk is found mixed with a vast quantity of shells, and this bed is eleven feet thick.

thick. Under this vegetables are found again with leaves and branches of trees as before; and thus alternately chalk and vegetable earth, to the depth of sixty-three feet. These are the layers whenever the workmen bore; while in many of them they also find pieces of charcoal, bones, and bits of iron. From this description it appears, that this country has been alternately overflowed and deserted by the sea, one age after another: nor were these overflowings and retirings of trifling depths, or of short continuance. When the sea burst in, it must have been a long time in overflowing the branches of the fallen forest with its sediment; and still longer in forming a regular bed of shells, eleven feet thick over them. It must have therefore taken an age, at least to make any one of them layers; and we may conclude, that it must have been many ages employed in the production of them all. The land also, upon being deserted, must have had time to grow compact, and to be drain'd of its waters before it could be disposed to vegetation.

Likewise in cutting a channel for the canal of Newry, in Ireland, a great multitude of fallen trees was discovered, lying near two miles in length, and in many places, six or eight feet deep. Many of these are very large, and are tumbled down one over another, some lying in strait lines, and others in an oblique or transverse position. If trees thus found had been felled by the deluge, (as undoubtedly others were) they would all lie in one position. But this is not the case. We must therefore seek for other causes. And one cause seems to have been this. If water flowing either from springs or streams be stopt, it
naturally

naturally softens and loosens the earth; and in a course of time, even to the roots of trees, which are then subject to be overturned by any violent storm. This doubtless was the case with most of those trees, that are found in bogs with the roots adhering to them. Trees thus falling sink into the yielding soil, and cause a farther stoppage in the course of the waters. Hence the loose earth is increased, by a yearly accession of scurf, moss, grass, and weeds. Add to this, that the higher lands being gradually dissolved by repeated rains, and washed down by floods, in a long course of years, cover the lower grounds with fresh layers of earth. This being so, it is not strange to find trees buried eight or ten feet under the earth.

Another cause may be this. Various colonies from time to time arriving in the then uncultivated country of Ireland, would naturally make room for tillage and pasture, by clearing the ground of its forests. This was certainly the case, where we find in bogs, trees partly burned, and others bearing the mark of the axe. But sometimes these colonies were driven by the natives from their intended settlements, leaving the trees they had felled strewed over the plain, which stopping the waters, of course created bogs, that in process of time covered those trees to a considerable depth. Nay, as late as 1561 Tyrone and O'Donnél marching toward Kinsale, through Connaught, and laying the country waste, there is a great tract of ground, now a bog, which was then ploughed land.

That bogs in general grow but slowly may be gathered from a lump of coins of Edward IV. (probably lost in a purse which rotted away) taken up in a bog in Yorkshire, eighteen feet deep.

This

This was about 300 years before. So the bog had grown about a foot in eleven years, that is, somewhat above an inch in a year: although some seem to grow much faster.

Much more antient is the Great Level, or fenny ground, which contains about 300,000 acres, lying in the counties of Norfolk, Suffolk, Cambridge, the Isle of Ely, Huntingdon, Northampton, and Lincoln. This was once firm land. There have been found therein stones, bricks, and other materials for building. In setting down a sluice, there was found sixteen feet deep, a smith's forge, and all the tools thereunto belonging. William of Malmſbury, who lived 1200 years ago, says that in his time, "The trees which grew there, smooth and strait, were so tall that they seemed to touch the stars. A plain there is, as even as the sea, which with the green glass, allures the eye; and there is not the least parcel of ground that lies waste and void. Here you see plantations of fruit-trees; there a field set with vines, part creeping on the ground, part mounting on high poles." But how came it to be reduced to so very different a state? It seems the ocean broke in upon it, with such resistless violence, that the buildings throughout the whole space were overturned, and the trees torn up by the roots. The amazing quantity of silt thrown up at the same time, covered the whole country, even to the verge of the Highlands, seven, eight, or even ten feet deep. Hence a few years since in digging a pool, there was found at the upper skirts of the level, the skeleton of a large fish, near twenty feet long, lodged in silt above six feet below the surface of the ground. Yet how or when this inundation was, we are not able to determine.

mine. Whenever it was, it was probably occasioned by a violent earthquake.

A late writer gives the following account of the natural origin of Bogs in Ireland. Some of these have vast quantities of timber under them: others have very little. But the surface of all is covered with a short, thick, and matted kind of heath. This as it grows and thickens at the top, vegetates at the bottom into a close texture, which being replete with moisture, throws out annual growths of this ramified heath, part of which dies every winter, and moulders at the bottom, where it forms another stratum, from which at spring comes a new crop of heath. And thus as these strata of mouldered heath are annually repeated, the roots increase, and at once extend higher, and are more consolidated at the bottom. Hence the turf is ever found of a closer texture, as we descend deeper in the Bog.

The turf itself is only a closely concreted combination of the roots of this heath, which universally grows on the surface of these bogs; not the produce of the trees which are at the bottom. Wherever these were thrown down, some earth would be washed down upon them from the adjacent grounds, the surface of which every where produces this heath. And this being now supplied with constant moisture, would throw out a more plentiful growth.

The same cause produces these bogs on the sides or even tops of mountains. But it is ever in wet grounds, or in flats on the side of hills where the water settles, and supplies them with moisture.

There seems indeed to be a spongy quality in this heath, which prevents the moistures sinking
away

away from it, by an attraction of the fluids, by an infinite number of capillary fibres, which are the very substance of it. At the bottom of these Mountain-Bogs, no trees are found. And very few in the largest bogs, unless on the skirts of them.

The turf then from top to bottom is entirely the produce of a vegetation from itself. And the reason why Ireland produces so many turf-bogs, is because it so abounds with the feeds of this heath, which is every where found where the land is uncultivated, and forms bogs, wherever it has proper moisture.

Our marle is found only in the bottom of low Bogs, at the depth of seven, eight or nine feet. For three feet is a spongy sort of earth, then gravel for about half a foot. For about three feet more is a spongy earth, mixed with timber, but so rotten, that it cuts like earth. Next this for the depth of three inches we find leaves, that are fair to the eye, but will not bear a touch. With these are sometimes mixed heaps of seed, which seem to be broom or furz seed: nay, in one place what seemed to be gooseberries and currants, was found, and sea-weed in others. Under this was blue clay half a foot thick, thoroughly mixed with shells, as was also the marle, which lay next, three or four feet deep. They are shells of periwinkles: and among these are large horns and bones answerable thereto. But it is not only in Bogs that subterraneous trees are found; nor in Ireland only, but in many parts of England. At Youle, about twelve miles from York, near the place where the Dun empties itself into the Humber, abundance of them have been dug up from time to time; all of which are a species of fir.

In

In the isle of Axholme in Lincolnshire, not firs only, but abundance of oaks are found in the Moor, whereof some are five yards in compass, with quantities of acorns near them. The Firs lie somewhat deeper than the oaks; one of them was thirty-six yards long. The adjoining levels (about 180000 acres) were half of them yearly covered with water, till King Charles I. sold them to Sir Cornelius Vermuyden, who drained them at the charge of above 400,000l. In the soil of all this land, through all Marshland, and on the skirts of all the Lincolnshire and Yorkshire wolds, are found millions of roots and bodies of trees, firs, oaks, birch, beech, yew, willow, and ash. The roots stand in their natural postures, as thick as ever they could grow. The bodies of most of the great trees, lie all their length about a yard from their roots with their tops north-east. The smaller lie across in every direction, some under, some above them. Some of the oaks are thirty, some thirty five yards long, yet wanting some yards at the small ends. They are firm, lasting, and as black as ebony. Many of them have been burnt, some quite through, some on one side. Some have been found chopped and squared, some bored through; some half cleft with great wooden wedges in them, and broken axe heads, shaped not unlike the sacrificing axes. And all these were in such places, and at such depths, as could not have been opened, from the time the forest was destroyed until the ground was drained. Near a great root in the Parish of Hatfield, were found eight or nine Roman Coins: and at the bottom of a new drain, were found trees squared and cut, rails, bars, a kind of battle axe, and two or three coins of the Emperor Vespasian. Nay, the ground

ground at the bottom of the river was found to lie in ridge and furrow, manifesting that it had been ploughed. In an old drain, an oak was found forty yards long, four yards in diameter, at the great end: three yards and a foot in the middle, two yards at the small end, so that by a moderate computation, it seems to have been as long again. Yea, about fifty years ago, there was found several feet deep, a man lying at his full length, with his head upon his arm as asleep. His skin, tanned as it were, by the moor-water, preserved his shape entire; but his flesh and most of his bones were consumed.

These stately trees formerly composed one of the most beautiful forests in the world. But how came it to be destroyed? When the Romans pursued the Britons, they always fled into the woods. On this the Roman Generals ordered them to be cut down; this vast forest in particular. The trees falling cross the rivers which ran through the country, soon dammed them up, turned the ground into a lake, and gave rise to the Moors, that increased continually, by earthly matter washed down, the consumption of rotting branches and leaves, and the growth of water-moss, which wonderfully flourishes on rotten grounds. Hence it is, that so many Roman Coins have been found at the bottom of these levels; that so many trees are found burnt or chopped; and that the soil of the country in general is two, three or more yards higher than formerly.

Some similar alteration seems to have happened many centuries ago, to that whole tract of land, near Newbury in Oxfordshire, out of which they
dig

dig their Peat. There is a stratum of this several miles, which lies many feet under the surface.

The best peat has very little (if any) earth in it, but is a composition of wood, branches, twigs, leaves, and roots of trees, with grafs, straw, plants, and weeds. The colour is of a blackish brown: and if it be chewed between the teeth it is soft, and has no gritty matter in it. It is indeed of a different consistence in different places, some being softer and some harder; which may arise perhaps from the different sorts of trees it is composed of. Great numbers of trees are visible in the true peat, lying irregularly one upon another, and sometimes even cart-loads of them have been taken out: but the nearer these trees lie to the surface, the less sound is the wood; and sometimes the small twigs which lie at the bottom, are so firm as not to be easily cut through: these trees are generally oaks, alders, willows, and firs, besides some others not easily known. The small roots are generally perished, but yet have sufficient signs to shew that the trees were torn up by the roots, and were not cut down; there being no sign of the axe or saw, which had they been felled, would have been plainly visible. A great many horns, heads, and bones of several kinds of deer, horns of the antelope, heads and tusks of boars, and heads of beavers, are also found in it, and some human bones.

Before we dismiss this subject, it may not be improper to subjoin as strange an account as any age can parallel. June 7, 1697, near Charleville in Ireland, a great rumbling was heard in the earth. Soon after, in the bog of Kapanihane, stretching

stretching north and south, some meadow and pasture land, that lay on the side of the bog, separated by a large ditch, and other land on the further side adjoining to it, began to move: and a little hill in the middle of the bog, sunk down.

This was at seven in the evening, the ground fluctuating in its motion, like the waves of the sea. The pasture-land then rose up, over-ran the ground beneath, and moved upon its surface, rolling on with great violence, till it had covered the meadow sixteen feet deep. It drew after it the body of the bog, part of it lying on the place where the pasture-land was before, leaving great breaches behind it, and currents of water, which cast up noisome vapours. There are still cracks and chasms through the whole surface of the bog, which contains forty acres.

But we have a later incident of the same kind. On Saturday, January 26, 1745, a part of Pilling-Moss, lying near Hescomb-houses, was observed to rise to a surprising height. After a short time it sunk as much below the level, and moved slowly toward the south-side. In half an hour it covered twenty acres of land. The improved land, adjoining to that part of the bog, is a concave circle, containing near an hundred acres, which is well nigh filled up with bog and water. In some parts, it is thought to be five yards deep.

An intense frost retards its progress for the present, but it is likely to spoil a great deal more land. That part of the Moss, which is sunk like the bed of the river, runs north and south. It is above a mile in length, and near half a mile in breadth.

Perhaps

Perhaps some Morasses have been ever since the deluge. In some of these are found, many feet deep, whole forests of timber, and frequently of such sorts as have not grown in those countries for many ages.

But some Morasses are only of late date. Lord Cromartie gives a remarkable account, of what he himself observed with regard to the generation of such a Morass. In the parish of Lockburn he saw, near the top of a very high hill, a plain about a mile over. It was then covered with a standing wood, but so old, that the trees had neither leaves nor bark left. When he came by the place fifteen years after, he observed all the trees were fallen. A few years after that, they were quite covered over with a soft, spongy earth, which formed a proper Bog or Morass. Many have been formed the same way.

The discovery of the Bones of Elephants at the bottom of some of our English Bogs, seems a convincing proof, that the earth has undergone some very extraordinary alterations. For the remains of animals of quite different climates, which in the present situation of the world, could never possibly come over thither, must imply, their having been originally here, or that England was once joined to the continent. But since we find these creatures only in the very hot countries, it is highly probable, they were not originally here, unless we suppose the temperature of our climate to have been greatly altered. And without such a supposition, we cannot suppose they would have wandered hither, though all parts of the globe had been contiguous. But what changes have happened to our earth, no human wisdom can find out. Suppose only the axis thereof to have been

been shifted at any time but a few degrees, what convulsions in nature, what an universal change in the face of things must have ensued? What inundations of water, beating every thing before them? What breaches in the earth, what hurricanes and tempests, must have attended such an event? For the waters must have rolled along, till an equipoise was produced. And all parts of the world must acquire different degrees of heat and cold from what they had before. Seas would be formed, where continents had been; continents torn in pieces, or split into islands. Such would have been the fate of inanimate things. And as to living creatures, they must have been destroyed and buried in the ruins of the world, as perhaps these elephants were.





C H A P. II.

1. *Of the effects and nature of fire :*
2. *Of the generation and nourishment of it.*
3. *Of smoke and ashes.*
4. *Of burning mountains.*
5. *Of Mount Ætna.*
6. *Of Mount Vesuvius.*
7. *Of Monto Secco.*
8. *Of Monte Nuevo.*
9. *New Islands.*
10. *Burning Islands.*
11. *Of Mount Hecla.*
12. *Of Guadeloupe.*
13. *Of the Pike of Teneriff.*
14. *Of Earthquakes.*
15. *Destruction of Port-royal in Jamaica.*
16. *———— of Lima.*
17. *———— of Callao.*
18. *A remarkable deliverance.*
19. *Of Pools and of Elden Hole.*
20. *Earthquakes caused by Electricity.*
21. *Account of a burning well.*
22. *———— of one near Brosely.*
23. *A Fire of the same kind.*
24. *A burning vapour.*
25. *Persons consumed by internal fire.*
26. *Sparkles from a person's cloaths.*
27. *Of glass.*
28. *Of the Bologna phial.*
29. *Of the glass-drop.*
30. *Of the nature and properties of air.*
31. *Air in all our fluids.*
32. *— is the cementing and dissolving principle.*
33. *— increases the weight of oil and vitriol.*

34. *Air*

34. *Air capable of immense expansion.* 35. *Difference between fix'd & common air.*

1. **T**HE Effects of Fire are various. It heats, it shines, it expands, it dissolves other bodies, either by melting or reducing them to ashes or a calx. Most of these argue a vehement motion of its particles, which tears asunder whatever it seizes. It seems to be a most subtle matter, dispersed throughout the universe. Yet this, even when collected soon scatters again, unless it be detained by some inflammable matter. Not that Fire will spring from every motion: it must be circular, as well as rapid. For if particles move ever so swift in a straight line, no Fire will follow.

Heat seems to be nothing but motion: but this motion has some peculiar circumstances.

1. It is expansive motion, whereby a body endeavours to dilate itself. 2. This motion is upward, and toward the circumference: 3. it is not an equable motion of the whole, but only of the smaller particles of the body: 4. it is a rapid motion. Heat may therefore be defined, an expansive, undulatory motion in the minute particles of a body, whereby they rapidly tend to the circumference, and at the same time upward.

Yet Fire has some effect on most bodies, even in an exhausted receiver. One placed a black ribbon therein, and then applied a burning-glass. Abundance of smoke issued out of it, which fell by little and little, and the ribbon appeared not at all changed. But when it was touched, after

the re-admission of the air, it presently fell into ashes.

The glass being applied to gun-powder so inclosed, it burnt grain by grain, but none of the grains kindled. Another time, when the sun had less force, they would not burn, but only boiled and emitted smoke. This smoke falling on the board on which the powder lay, was of the colour of brimstone. The powder that remained, being put on coals, burned like saltpetre, inasmuch as the brimstone had exhaled.

Tin and Copper melted together weigh more than both bodies did before. Yea, Orpin being mixed with salt of Tartar, is heavier by a fifth part.

To account for this, it has been commonly supposed, that fire adds to the weight of bodies. But fire has itself no weight at all: therefore it can give none. Pure Fire, as Dr. Hillary observes, is a body without gravity, and has no more tendency to any one part of space, than to any other.

Is not then this alteration of weight rather owing to an alteration of the inward texture of the particles in the body calcined? The lighter particles being removed by exhalation, do not those remaining approach nearer each other? And must not then the weight, which is always as the solidity, increase accordingly?

It seems strange, to talk of heating cold liquors with ice. Yet it may easily be done thus. Out of a basin of cold water, wherein several fragments of ice are swimming, take one or two, and plunge them into a wide-mouthed glass of strong oil of vitriol: this quickly melts the ice, and by

two or three shakes, the liquor grows so hot, that frequently you cannot endure to hold the phial in your hand.

It may seem as strange, that those parts of the earth, which are nearest the sun should be intensely cold. Yet so it is. For the higher you ascend on mountains, the colder is the air. And the tops of the highest mountains in the most sultry countries are eternally clothed with snow. This is partly owing to the thinness of the air, partly to the little surface of earth there, to reflect the solar rays.

Thus very different degrees of heat, obtain in the same latitude, on the different sides of the South American Continent: which shews that the temperature of a place depends much more upon other circumstances, than upon its distance from the pole, or nearness to the equinoctial. Thus though the Coast of Brazil is extremely sultry, yet the coast of the South Seas in the same latitude is quite temperate, and in ranging along it, one does not meet with so warm weather, as is frequent in a summer's day in England: which is the more extraordinary, as there never falls any rain to refresh and cool the air. On the coast of Peru, even under the line, every thing contributes to make the day agreeable. In other countries, the scorching sun in summer, makes the day unfit either for labour or amusement: and the rains are no less troublesome, in the cooler parts of the year. But in this delightful climate, the sun rarely appears; for there is constantly a grey, chearful sky, just sufficient to screen the sun, without obscuring the air. Thus all parts of the day are pro-

per for labour, while the coolness produced elsewhere by rains, is here brought about by fresh breezes, from the cooler regions.

This is chiefly owing to the Andes, which running not far from, and nearly parallel with the shore, and rising immensely higher than any other mountains in America, form on their sides a prodigious tract of land, where according to their different heights, all kinds of climates may be found, at all seasons of the year. These mountains intercept great part of the eastern winds, which generally blow on the continent of America, cool that part of the air which comes over their tops, and keep it cool by the snows, with which they are always covered. Thus by spreading the influence of their frozen crests, to the neighbouring coasts and seas, they cause the temperature and equability which constantly prevail there. But when they leave these mountains, they experience in a short time an entire change of climate, and in two or three days pass from the temperate air of Peru, to the sultry atmosphere of the West Indies.

The sparks which appear on striking Fire with a flint and steel, are discovered by the microscope, to be so many spherical balls of iron, detached by the blow from the mass. They are then red hot. After they cool, they are a sort of scoriæ or dross.

2. Fire is Generated chiefly, either by collecting the sun-beams by a glass, or by rubbing hard bodies against each other. Either way the subtle matter is collected from all sides, and put into a rapid, circular motion. This continues together, as long as it is supplied with inflammable substances.

The

The particles of these being divided by the Fire, are scattered hither and thither, and the fire goes out unless fresh fuel be brought : as it does if air be wanting. For as that subtle matter is dissipating continually, it soon fails, unless recruited from the air. If water or dust be thrown upon Fire, it is likewise quickly extinguished. For these interrupt that internal motion, which is essential to it.

That fuel cannot consume without air is clearly proved by an easy experiment. Let a strong hollow cylinder of iron, be fitted with a firm screw at each end. Inclose in this a piece of charcoal: then screw up both ends, and place it in a strong fire. Let it stay there as long as you will. Open it when cool, and the charcoal is no way diminished. It is plain from this, that the consumption of fuel depends on the rarefaction and agitation of its parts by fresh air. And hence we have the reason of the known method, of extinguishing Fires by smothering them.

3. The watry part of the fuel being rarefied by the heat, ascends in the form of Smoke, carrying with it many of the lighter particles, which adhere as soot to the chimney. The grosser and more compact, the contexture whereof the Fire cannot wholly destroy, remain and constitute ashes, which are of consequence extremely porous, all that was combustible in it being consumed.

To enlarge a little on this subject. Fire is a body, and a body in motion. It is in motion ; for it expands the air, which can no otherwise be done, than by communicating motion to it. And that it is a body appears hence. Pure mercury inclosed in a phial, and kept in a gentle heat for
E 4
a year,

a year, is reduced into a solid. And its weight is considerably increased, which can only spring from the accession of fire.

Fire is the instrument of all the motion in the universe. Without it all bodies would become immoveable. Men would harden into statues: and not only water, but air cohere into a firm, rigid mass.

As it is in itself, it is termed *Elementary Fire*: joined with other bodies it is called *Culinary*. The minute particles of this, joining with those of the pure Fire, constitute what is termed Flame. Pure Fire, such as is collected by a burning glass, yields no flame, smoke, or ashes. In itself it is imperceptible, but is discovered by its *effects*. The first of these is *heat*, which arises wholly from Fire, and the measure of heat is always as the measure of Fire. The second is, *dilatation* in all solid, and *rarefaction* in all fluid bodies. So an iron rod, the more it is heated, increases the more in all its dimensions. And by the same degrees that it cools, it contracts, till it shrink to its first magnitude. So gold, when fused takes up more space than it did before. And mercury ascends in an hollow tube over the fire, to above thirty times its former height. The same degree of heat rarefies fluids sooner, and in a greater degree than it does solids. And the lighter the fluid, the more it is dilated. Thus air, the lightest of all fluids, expands the most. The third effect of Fire is *motion*: for in dilating bodies, it must needs move their parts. All motion springs from it. Only take Fire away, and all nature would grow into one concrete, solid as gold, and hard as diamond.

Pure Fire needs no air to sustain it. Put calx of tin into an exhausted receiver, and if you apply a burning

burning glass, the calx will be so vehemently dilated, as to break the receiver into a thousand pieces.

All the effects of elementary Fire may be increased. 1. By rubbing one body against another. And the more hard and solid the bodies are, the more heat is produced. So sponges rubbed together acquire little or no heat: but two pieces of iron, an intense heat. 2. By mixing certain bodies together. So steel-filings mixed with oil of cloves or spirit of nitre grow exceeding hot; yea, burst into a violent flame.

Yet it does not appear that any new Fire is generated in any of these ways. Friction does not create Fire, but only collect what was before dispersed. It is present every where, in all bodies, in all space, at all times, and that in equal quantities. Go where you will, to the highest mountain, or the deepest cavern, by one or other of these ways Fire may be collected. Yea, there is no place in the world, where the attrition of two sticks will not make it sensible.

But in what manner soever Fire is collected, if the collecting cause cease, it disappears again, unless it be supplied with fuel, and then it becomes Culinary Fire. By fuel we mean whatever receives and retains Fire, and is consumed thereby. The only fuel in nature is oil or sulphur, and bodies are only fuel, as containing oil; Hence 1. All vegetables, not too moist or too dry, afford fuel, particularly those which contain much oil, as balsamic and resinous woods. 2. All vegetable and animal coals, being those parts which have exhaled their water and salt, and retained the oil alone inhering in the earth. 3. All bituminous earth. 4. All mineral sulphur, whether pure or

E 5
joined

joined with other things. 5. The fat and dung of animals: and 6. Chymical oil and spirits.

On the removal of air, this Fire goes out. Yet it does not immediately bear the air, but repels it, and by that means forms a kind of vault, which by its weight and the pressure of the incumbent air, confines the particles that would otherwise escape, and applies them to the combustible matter. Hence the heavier the air, the fiercer the Fire; which therefore is fiercest in still, cold weather.

The Fire in burning combustible matter, affords a shining fire or flame, or both: and frequently too, smoke, soot and ashes. Shining Fire seems to be elementary Fire, so strongly attracted toward the particles of the fuel, as to whirl, divide, attenuate them, and thus render them volatile, and just fit to be expelled. Flame seems to be the most volatile part of the fuel, greatly rarefied and heated red hot. Soot is a sort of coal, consisting of a thick sulphur, and an attenuated oil, with earth and salt. Smoke is the earthy and watry particles of the fuel, so rarefied as to break through into the atmosphere. Ashes are the earth and salt, which the fire leaves unchanged.

Fire increases the weight of some bodies. Thus if antimony be placed under a burning-glass, the greatest part of it will seem to evaporate in fumes, and yet if it is weighed, it will be found to have gained in weight.

But beside the solar, there is a subterraneous Fire. The earth is only cold to the depth of forty or fifty feet. Then it begins to grow warmer; and at a great depth it is so hot as to destroy respiration. Hence we learn that there is another source of Fire, or as it were another sun in the bosom of the earth.

Upon

Upon the application of Fire to water, it boils: that is, the particles of Fire, passing through the pores of the vessel, strike on the lowest particles of the water, impel them upwards, and render them lighter than before, both by inflating them into little vesicles, and by breaking and separating their spherules. There will of consequence be a constant flux of water, from the bottom of the vessel to the top. And hence we see, why the water is hot at the top, sooner than at the bottom.

Farther, the air contained in the interstices of the water being dilated, and its spring increased by the heat, it ascends through the water into the air, carrying with it the contiguous particles of water. And by this means much of the water will be heaved up, and let fall alternately, as the air has no power to carry away into the atmosphere more than that small part that rises in the steam.

4. That this subtle matter is plentifully collected in the bowels of the earth, appears from Burning Mountains. It is observed, that there is always in the neighbourhood of these, plenty of sulphur or bitumen, the stench whereof spreads far and near, especially before any great eruption. This feeds the Fire, which may be kindled by various means, so as to continue for many centuries. *Ætna* and *Vesuvius* have burned for above 2000 years, and probably will till the end of time.

5. Mount *Ætna* is divided into three distinct regions, called *La Regione Culta*: the Fertile Region: *La Regione Sylvosa*, the Woody Region; and *La Regione Deserta*, the Barren Region.

The three are as different, both in climate and productions, as the three zones of the earth: and

perhaps with equal propriety might have been filed the torrid, the temperate, and the frigid zone. The first region surrounds the foot of the mountain, and constitutes the most fertile country in the world on all sides of it, to the extent of about fourteen or fifteen miles, where the woody region begins. It is composed almost entirely of lava, which, after a number of ages, is at last converted into the most fertile of all soils.

Every eruption generally forms a new mountain. As the great crater of *Ætna* itself is raised to such an enormous height above the lower regions of the mountain, it is not possible that the internal fire raging for vent, even round the base, and no doubt vastly below it, should be carried to the height of twelve or thirteen thousand feet, from the summit of *Ætna*. It has therefore generally happened, that after shaking the mountain and its neighbourhood for some time, it at last bursts open its side. At first it only sends forth a thick smoke, and showers of ashes, that lay waste the adjacent country: these are soon followed by red-hot stones, and rocks of a great size, thrown to an immense height in the air. The fall of these stones, together with the quantity of ashes discharged at the same time, at least form one of these spherical and conical mountains. Sometimes this process is finished in the course of a few days: sometimes it lasts for months, which was the case in the eruption in 1669. In that case the mountains formed are of a great size; some of them are not less than seven or eight miles round, and upwards of one thousand feet in perpendicular height: others are not more than two or three miles round, and three or four hundred feet high.

After

After the new mountain is formed, the Lava generally bursts out from its lower side; and bearing away every thing before it, is for the most part terminated by the sea. This is the common progress of an eruption; however, it sometimes happens, though rarely, that the lava bursts at once from the side of the mountain, without all these attending circumstances; and this is commonly the case with the eruption of Vesuvius, where the elevation being so much smaller, the melted matter is generally carried up into the crater of the mountain, which then discharges showers of stones and ashes from the mouth of the volcano, without forming any new mountain, but only adding considerably to the height of the old one; till at last the lava, rising near the summit, bursts the side of the crater, and the eruption is declared. This has been the case with two eruptions lately; but *Ætna* is upon a much larger scale, and one crater is not enough to give vent to such oceans of liquid fire.

Recupero saw in an eruption of that mountain, large rocks of fire discharged to the height of some thousand feet, with a noise more terrible than that of thunder. He measured from the time of their greatest elevation, till they reached the ground, and found they took twenty-one seconds to descend, which (the spaces being as the squares of the times) amounting to upwards of 7000 feet.

After contemplating these objects for some time, says a late traveller, we set off, and soon after arrived at the foot of the great crater of *Ætna*. This is of an exact conical figure, and rises equally on all sides. It is composed solely of ashes, and other burnt materials, discharged from the

the mouth of the volcano, which is in its center. This conical mountain is of a very large size: its circumference cannot be less than ten miles. Here we took a second rest, as the greatest part of our fatigue still remained. The mercury had fallen to $20\ 4\frac{1}{2}$. We found this mountain excessively steep; and although it had appeared black, yet it was likewise covered with snow, but the surface (luckily for us) was spread over with a pretty thick layer of ashes, thrown from the crater. Had it not been for this, we never should have been able to get to the top.

The circumference of this zone or great circle on *Ætna* is not less than seventy or eighty miles. It is every where succeeded by the vineyards, orchards and corn-fields that compose the *Regione Culta*, or the Fertile Region. The last zone is much broader than the others, and extends on all sides to the foot of the mountain. Its whole circumference, according to *Recupero*, is 183 miles.

The present crater of this immense volcano is a circle of about three miles and a half in circumference. It goes shelving down on each side, and forms a regular hollow, like a vast amphitheatre. From many places of this space, issue volumes of sulphureous smoke, which being much heavier than the circumambient air, instead of rising in it, as smoke generally does, immediately on its getting out of the crater, rolls down the side of the mountain like a torrent, till coming to that part of the atmosphere of the specific gravity with itself, it shoots off horizontally; and forms a large tract in the air, according to the direction of the wind; which happily for us, carried it exactly to the side opposite to that where we were placed.

placed. The crater is so hot that it is very dangerous, if not impossible, to go down into it: besides, the smoke is very incommodious, and in many places the surface is so soft, there have been instances of people sinking down into it and paying for their temerity with their lives. Near the center of the crater is the great mouth of the volcano. That tremendous gulph so celebrated in all ages. We beheld it with awe, and with horror, and were not surpris'd that it had been considered as the place of the damned. When we reflect on the immensity of its depth, the vast cells and caverns whence so many lavas have issued; the boiling of the matter, the shaking of the mountain, the explosion of flaming rocks, we must allow that the liveliest imagination hardly ever formed an idea of hell more dreadful.

Kircher pretends to have measured it, and to have found it four thousand French toises in height; which is more than any of the Andes are. The Italian Mathematicians are still more absurd. Some of them make it eight miles, some six, and some four. Arnici, the last, and I believe the best who has made this attempt, reduces it to three miles, two hundred and sixty-four paces; but even this must be exceedingly erroneous, and probably the perpendicular height of *Ætna* is little more than two miles.

It is a curious consideration that this mountain should re-unite every beauty and every horror; and in short, all the most opposite and dissimilar objects in nature. Here you observe a gulf, that formerly threw out torrents of fire now covered with the most luxurient vegetation; and from an object of horror becomes one of delight

light. Here you gather the most delicious fruits, rising from what was lately a black and barren rock. Here the ground is covered with every flower; and we wonder over these beauties, and contemplate this wilderness of sweets without considering that hell and all its terrors, is immediately under our feet, and that but few yards separates us from lakes of liquid fire and brimstone.

But our astonishment still increases, on casting our eyes on the higher regions of the mountain. There we behold in perpetual union, the two elements that are at perpetual war; an immense gulph of fire, for ever existing in the midst of snows, which it has not power to melt; and immense fields of snow and ice for ever surrounding this gulph of fire, which they have not power to extinguish.

The quantity of matter discharged from *Ætna*, is supposed upon a moderate computation to exceed twenty times the original bulk of the mountain. The greatest part of Sicily seems covered with its eruptions. The inhabitants of *Catanea* have found at the distance of several miles, streets and houses, sixty feet deep, overwhelmed by the lava or matter it has discharged: nay the walls of these very houses have been built of materials evidently thrown up by the mountain. The inference is obvious: that the matter thus exploded cannot belong to the mountain itself: otherwise it would have been quickly consumed: it cannot be derived from moderate depths: since its amazing quantity evinces that all the places near the bottom, must have long since been exhausted: it must therefore be supplied from the deeper regions of the earth; these undiscovered tracts, where

where the Deity performs his wonders in solitude.

An eruption of Mount *Ætna* in 1669 was preceded for eighteen days, with a dark, thick sky, thunder, lightening, and frequent tremblings of the earth. The place of eruption was twenty miles from the old mouth: the matter of it was a stream of melted minerals, boiling up and gushing out, as water does at the head of a great river. Having run thus for more than a stone's cast, the extremities began to crust, and turn into porous stones, resembling huge cakes of sea coal, full of a fierce fire. These came rolling over one another, and where any thing opposed, filled up the space and rolled over. But they bore down any common building, and burnt up all that was combustible. This inundation went on about a furlong a day, for nineteen or twenty days. It overwhelmed fourteen towns and villages. The noise of the eruption was heard sixty miles.

On Sunday, March 9, 1755, about noon, Mount *Ætna* began to cast from its mouth a great quantity of flame and smoke, with a most horrible noise. At four o'clock the air became quite dark and covered with black clouds. At six a shower of stones, each weighing about three ounces, began to fall over all the city of *Mascali* and its territories. This shower lasted till a quarter past seven; and was succeeded all night by a shower of black sand. On Monday morning at eight, there sprang from the bottom of the mountain a river of scalding-hot water, which in half a quarter of an hour, overflowed all the rugged land that is near the foot of the hill, and suddenly going off, left the whole a large plain of sand. The stones and sand which remain wherever this water reached, differ

differ in nothing from the stones and sand of the sea, and have even the same saltness. After the water was gone there sprang from the same opening a small stream of fire, which continued for four and twenty hours. On Tuesday about a mile below this opening, there arose another stream of fire, which being in breadth about four hundred feet, overflowed all the adjacent country.

6. On the 3d of December, 1754, a stream of liquid Fire, began to run down the side of mount Vesuvius, from an opening on the east side. But it soon ceased running from this orifice, and burst out from a much larger one, about two hundred yards below it. Afterward it burst out from a third orifice, and having ran some space with great fury, the surface then began to cool and incrust, as it ran over gently-declining ground, till it came within about ten yards of the top of a steep declivity. Here the Fire collected, as in a reservoir, to supply a cascade, which rushed down from thence in a channel of more than twenty feet wide, and about two hundred yards in length, with a fall of at least fifty feet. After this the stream was less rapid, but grew wider, and spread several miles from its source. It now presented a very different scene from what it afforded before. The cascade (says an eye-witness) looks like melted gold, and tears off large bodies of old Lava (so they term the incrustation) which float down the stream, till the intenseness of the heat lifts them from the bottom. But in the lower country, it divides into smaller streams, running with less rapidity: and yet with such violence, that it drives the strongest stone-fences before it, and

and lighting the trees, like torches, affords a most extraordinary, though dismal spectacle.

On December 23, 1760, about two in the morning, a violent shock of an earthquake was felt, near Mount Vesuvius. Some time after, some countrymen being at work, four or five miles from it, perceived the ground near them on a sudden heave and gape, like dough that is rising. At the same time they observed smoke issuing from the clefts. They immediately fled, till they thought they were out of danger. And then looking back, saw the water of a cistern, near which they had been at work, spout out to a great height. This was succeeded by a large discharge of fiery matter from the mouth of the cistern, and from four other openings, attended with a dreadful noise and explosion of burning stones. On a sudden all the fiery streams united in one, flowed impetuously down the mountain, and gliding quick as lightning, presently covered all the adjacent lands. Mean time the whole mountain shook greatly, and a fixed pillar of smoke issued out of the main aperture, which rising to a certain height, then dissolved into ashes, and fell like rain all over the mountain. At the same time an immense quantity of burning stones was thrown out.

The fiery stream continued running down the mountain, the whole night between the 23d and 24th. Houses, Gardens, and every thing in its way, were consumed. And ashes were still thrown out, which lay deep on the ground for several miles about, and reached as far as the sea-coast.

On the 25th also there was an eruption of liquid fire, with a shower of stones, and a huge noise. In several parts this stream was fifty spans deep

deep. The mountain mean time continued to roar, and thick ashes fell like rain over the whole country.

On the 26th both the mountain itself and the hills lately produced, sent forth stones and ashes. the bellowings were still heard, but with intermissions: and out of the five apertures, two only continued to emit stones, ashes, and fire.

On the 27th only one fiery stream remained, and that began to cool, and to lose its brightness, appearing more dusky, like burning coals ready to go out. On the 28th the stream ran much slower, and no more burning stones were cast out. The height of the chief hill raised thereby was about two hundred spans; and its circumference about two hundred paces. The motion of the Lava in front was very slow; it gained ground only on the sides. The hill, where the last aperture was, burst, and Fire issued from all the fissures.

On the 29th, the Lava having ceased, appeared to have reached about a mile in breadth and four miles in length. The new-raised hills were now quiet: but the top of Vesuvius still cast out ashes and smoke and some showers of stones. About eight at night the new hill was overturned with a great crack, and on the 30th emitted nothing. But from the mouth of Vesuvius clouds and ashes came in great abundance. From the whole it appears, that the inflammatory contents take Fire at a great depth in the cavern, and it is highly probable, it is the sea-water which feeds this subterraneous fire, by means of some communications which the Volcano has with the Mediterranean.

Although the fiery eruptions of mount Vesuvius strike the neighbourhood with horror; yet as even noxious things bring some advantage with them; so this mountain by the sulphureous and
nitrous

nitrous particles with which it manures the ground, and the heat of its subterraneous passages, much contributes to its uncommon fertility. And wherever these inflammable substances abound, it is better they should have a vent than not. So experience shews; that this country has had fewer earthquakes, and those less fatal in their effects, since the eruption of the subterraneous matter, through the mouth of Vesuvius. And the inhabitants are not much alarmed, at seeing the usual vernal explosions.

The distance from Naples to the foot of Vesuvius, is five Italian miles, from whence to the top is near three miles further. It properly consists of two hills, though one of them only, emits Fire and smoke. The valley between them is about a mile long, and extremely fertile. The burning summit, which is the lowest of the two, is eleven hundred fathoms above the surface of the sea. From Refina, the ascent grows steeper, and many stones are scattered about, as memorials of its former devastations. It is astonishing to think of the force, by which such huge bulks of four or five hundred weight have been thrown several miles from the hill.

This being steep, and covered with black ashes, the ascent is very difficult. From the mouth frequently issues a flood of Lava, or composition, of sulphur, metals, and minerals. This ejected matter lies still one layer above another, with large stones projecting above the surface, which in their course along the fiery river, were stopped by their inequalities, and fixing in the melted matter, gradually hardened. These streams are not thrown up from the mountain, like the stones, but pour down as from an inclined vessel, proceeding, it seems

seems, from the whole cavity, which is then full of melted substances.

About half way up the mountain (says Mr. Keyster) we met with stones above of an hundred weight, glowing hot, which when broken had exactly the appearance of red hot iron. As we went on, we heard a most horrid noise, resembling the discharge of a whole battery of cannon, and under our feet we perceived a rumbling, like the boiling of a large caldron. At last we reached the place where the largest volcano was formerly situated. But it is now not only choaked up but covered with a round pile of ashes and lava. Thirty years since there was a plain of about three thousand yards to cross, before you came to the skirts of this new mountain. But it is now so enlarged, that in most places, the plain is but about thirty yards broad. Probably in a few years it will be quite filled up, and the two mountains joined in one. Here the increase of heat was very sensible, especially at every explosion, when the ashes flew so strongly in our faces, that we were obliged to cover our eyes. The ground also was so hot under our feet, that it burnt the soles of our shoes. Every eruption was attended with a whizzing noise, like that of many rockets thrown up at once. The clouds of smoke, and the multitude of stones thrown into the air, totally obscured the sky. Most of the stones, (especially if large) fell again into the abyfs from which they were projected. Great quantities however fell on the sides of the mountain, and rolled down with a hideous noise.

Even when all is still, the bottom of the cavity is seldom seen, by reason of the smoke. When it is it is subject to great variation. Sometimes it is a pre

a prodigious depth; at other times hardly more than an hundred feet, according to the rising or falling of the melted matter, since the last eruption, by the hardening of which, this bottom is formed.

Since the birth of Christ, there are recorded upwards of twenty memorable eruptions of Vesuvius. One of the most violent was, that which happened in the reign of Titus Vespasian, and destroyed the cities Herculaneum, Stabice and Pompeii, which then stood near Naples. During that eruption the ashes were driven as far as Africa, Syria, and Egypt, and even at Rome, the sun was darkened by them. These cities were partly swallowed up, partly buried in the burning lava, so that not the least remains of them were to be seen.

But within a few years many things have been dug out of Herculaneum, near Portici, the King of Naples' palace. Among these are many paintings done in Stucco, in water colours in Fresco. They have been taken from the walls of an amphitheatre, a temple, and several houses, and are in great variety, some perfectly well preserved.

Four capital pieces are so extremely well executed that Don Francesco de la Vega, a painter, whom the king of Naples sent for from Rome, to take draughts of these paintings, said, "If Raphael were alive, he would be glad to study these drawings, and perhaps take lessons from them." Nothing can be more just and correct. The muscles are exactly and softly drawn, every one in its own place, without any of that preternatural swelling seen in the works of some of the best Italian masters. And it is surprising to see how fresh the colours are, considering they have been
under

under the ground above sixteen hundred and fifty years.

The matter thrown out of Vesuvius, shews whence its fiery eruptions arise. For, pour water on sulphur, mixed with filings of iron, and it soon breaks out into a flame. That abundance of sulphur and iron is contained in Vesuvius, appears not only from what is ejected, but also from the mineral water, issuing from the foot of the mountain. The neighbouring sea both supplies moisture to these inflammable substances, and also salt and bitumen. That Vesuvius has a communication with the sea, experience shews, the waters being surprisingly absorbed, in 1681, before the eruption, so that the several vessels before afloat were left dry. Likewise in 1698, the sea suddenly ebbed twelve paces and the mountain discharged a torrent of bituminous matter. When the discharge ceased, and the sea returned to its former height, great quantities of shells, half burnt, and emitting a sulphurous smell, were found along the shore. In another violent eruption, not only shells, but sea-weeds, and hot sea-water were ejected.

This volcano, however, affords several fresh springs, some of which are conveyed to Naples, by a beautiful aqueduct. These waters have not the least heat in them. Nay, a cold wind is left to blow, from several fissures and chasms of the mountain.

The whole country for twenty miles or more round Naples, is the product of subterraneous fires. Probably the sea reached the mountains that lie behind Capua and Caserta. These fires seem to have worked under the bottom of the sea, as moles in a field, throwing up here and there

there a hillock. And the matter thrown out of some of these hillocks formed into settled volcanos, filling up the space between them, has composed this part of the continent, and many of the islands adjoining.

Were the matter carefully examined, it would be found (just contrary to the common opinion) that most mountains which are or have been volcanos, owe their existence to subterraneous fires.

It cannot be denied that Herculaneum and Pompei once stood above the ground, though now the latter is buried ten or twelve feet deep; the former in no part less than seventy, in some parts an hundred and twelve. As these were buried by an eruption of Vesuvius, A. D. 79, it must be allowed, that whatever matter lies between them and the surface of the earth over them, must have been produced since this time.

Pompei being farther off, felt the effects of a single eruption only. It is covered with white pumice stones, mixed with fragments of lava and burnt matter. Over this there is a stratum of good mould, about two feet thick. The shower of pumice stones covered also the town of Stabiae, with a tract of country thirty miles in circumference. It is observable, the pavement of the streets of Pompei is of lava: nay, under the foundation of the town, there is a deep stratum of lava and burnt matter: hence it is clear, there have been eruptions before that of 79, the first which is recorded in history.

The matter which covers Herculaneum, is not the produce of one eruption only. From the strata of mould intermixed it appears, that five or six
 Vol. III. F eruptions

eruptions have taken their course over that which lies immediately above the town, with which the theatre, and most of the houses are filled. This is not vitrified lava, but a sort of soft stone, composed of pumice, ashes, and burnt matter. It is of the same nature with what the Italians call Tufa, and is in general use for building, and is met with only in those countries that have been subject to subterraneous fires. As water frequently attends eruptions of fire, doubtless the first matter that issued from Vesuvius, and covered Herculaneum, was in the state of liquid mud.

Bracini descended into the crater (or hollow on the top) of Vesuvius, a little before the eruption in 1631. He observes, it was then five miles in circumference, and about 1000 paces deep. Its sides were covered with brush wood, and at the bottom there was a plain on which cattle grazed. In the midst of this plain was a narrow passage, through which by a winding path he descended among rocks and stones into a more spacious plain, covered with ashes. In this were three little pools, one of hot water, bitter and corrosive beyond measure, another of water salter than that of the sea; the third, hot but tasteless.

The great increase of the cone of Vesuvius, from that time to this, naturally induces one to think, that the whole cone was raised in like manner, as was also that part of it now called Somma. It seems, that this was what the ancients termed Vesuvius, and that the conical mountain, at present called by that name, has been raised by the succeeding eruptions.

From repeated observations, it appears, that all the soil in the neighbourhood of Vesuvius, is composed

posed of different strata of erupted matter, to a great depth below the level of the sea. And undoubtedly this volcano took its rise from the bottom of the sea. The soil from Capriæ to Naples is of the same sort. And that on which Naples stands, has been evidently produced by explosions, some of them on the very spot whereon the city is built. All the high grounds round it, with the islands of Prochyta and Ischia, appear likewise to have been raised in the same manner.

Such wonderful operations of nature, are certainly intended for some great purpose. They are not confined to one country; volcanos exist in the four quarters of the globe. We see the fertility of the soil occasioned thereby, in what was thence called *Compania felix*. The same is evident in Sicily, justly esteemed one of the most fertile spots in the world. May not subterraneous fire be considered as the great plough (if we may be allowed the expression) which nature makes use of to turn up the bowels of the earth, and afford us fresh fields to work upon, when the former are exhausted? Perhaps likewise many precious minerals might have remained unknown to us, had it not been for these operations of nature.

There is great reason to believe that the whole Island of Madeira was at some remote period thrown up by the explosion of subterraneous fire, as every stone, whether whole or in fragments, that is seen upon it appeared to have been burnt; and even the sand itself to be nothing more than ashes. And it is certain, that part of the country near the sea is a very exact specimen of the rest

7. Near Puzzuolo lies Monte Secco, which is Vesuvius in miniature. Its summit, formerly a cone, is now sunk into a concave oval, whose shortest diameter is about one thousand feet, the longest one thousand two hundred and forty-six. It is generally known by the name of Solfatara. Though Vesuvius is twelve miles distant, yet they have a communication with each other. Hence the subterraneous Fire is quiet at Solfatara, when it has a vent at Vesuvius: whereas the heat at the former increases, when the latter is at rest.

On this mountain are many cracks emitting smoke; the heat issuing from them is sometimes insupportable. Hold a piece of iron over one of these cracks, and a sweetish fluid will drop from it: but a piece of paper, instead of being moistened, grows quite dry and stiff. The stones near these cracks are in continual motion; and small stones dropped into them are ejected to the height of twelve feet, like the ponderous masses from Vesuvius. In some places the sand by the force of the vapours, springs up and down, like the sparkling of cyder.

Out of Solfatara they extract beside sulphur, blue vitriol, and the best kind of allum. The large leaden kettles used therein, are not heated by a culinary fire, but by the natural heat, issuing through holes in the ground, over which the vessels are placed.

8. Not far from Puzzuolo is Monte Nuovo, which rose suddenly in the night, between the 19th and 20th of September, 1636. During a dreadful earthquake, that laid the whole neighbourhood in ruins, the subterraneous Fire, opening a large chasm in the ground, threw out such quantities of stones, ashes, bitumen, and sand,

land, as in twenty-four hours formed this mountain. Its perpendicular height is 400 rods, its circuit three miles. The edge of the first aperture is still visible, a mile in circuit, though it is now entirely filled up.

9. An event similar to this occurred more lately. After a shock of the earth, there was seen from Santorini (an island in the Archipelago, on the coast of Natolia) on the 23d of May, 1707, as it were a floating rock. Some were so bold, as to go down upon it, even while it was rising under their feet. The earth of it was very light, and contained a small quantity of Pottery Clay. It increased daily, till it was half a mile in circumference, and twenty or twenty-five feet high. At this time a great ridge of rocks, dark and black, rose out of the sea, and joined to the new island. Then there issued out of it a thick smoke, with a noise like constant thundering, or a discharge of many cannon at once. The sea-water continually bubbled up; and in a short time the new land presented nothing to view for whole nights, but a great number of stoves, which cast forth flames, with showers of ashes, and innumerable small stones, red hot. Rocks were also darted out of these burning furnaces, which mounted up like bombs. This continued till November.

There is likewise an island among the Azores, which had the same original. On the night between the 7th and 8th of December, 1720, there was felt a shock of an earthquake at Tercera; and presently after an Island rose, from the midst of boiling hot water. It was nearly round, and high enough to be seen seven or eight leagues off. But

after a little while it sunk, till it became level with the water.

10. On June 4th, 1693, the mountain on the island Torca in the East-Indies, began about day-break, to cast out more Fire than usual, which continued five or six days, till at last it poured forth, not only a prodigious flame, but likewise such a black and sulphureous vapour, that the inhabitants of Hillo (a village in the western part of the island, and nearest to the opening) were wholly covered by it. Quickly followed a stream of burning brimstone, which consumed many that could not escape. Afterwards the inhabitants perceived, a great part of the mountain was sunk down. Another part sunk three or four days after, and so from time to time, till the burning lake covered near half the island. Wherefore they went on board their boats: from whence they perceived huge pieces of the mountain fall into the fiery lake, with a prodigious noise, as if a whole battery of cannon was discharged. The inhabitants of another town on the east side of the island, not thinking themselves in so great danger, remained a month longer. But the fiery lake approaching nearer and nearer, so that there was no doubt but it would swallow up the whole island, they too fled for their lives, and arrived at Amboyna, July the 18th, 1693.

In the Mountains of Ternata, a terrible noise is continually heard. The fire frequently casts out stones, and lies exceeding deep. Probably the burning mountains in the Molucca Islands are consumed beneath by the same Fire.

Manilla

Manilla is one of the largest of the Philippine Islands. The city is much larger than Oxford, is an university, and is inhabited only by Spaniards. The houses are large, and built very strong. The lower walls are stone, and of a prodigious thickness. All above is wood, and every piece of timber has a connexion with the others, and all are jointed together, that the earthquakes which are very frequent may not throw them down. In 1750, they had an earthquake with almost continual tremblings for three months. Then followed an eruption in a small island, surrounded by a large lake, which is unfathomable. The third day after the eruption began, there arose in the lake four more small islands all burning. About a mile from one of these, there is a fire rising continually out of the water, in a part where there is no ground for above an hundred fathom.

11. A particular account of a journey to Mount Hecla, is given by a late author. We travelled, says he, two days in rugged and unfrequented roads. Then we came within six miles of the mountain, and perceived the ground strewed with ashes and pumice stone, over which we passed to the foot of it. The weather being serene and calm, and no flames issuing out of the volcano, we resolved to go to the top; till being informed by our guides, that if we went any further, we should be in danger of falling into pits, where we might be suffocated by the fumes rising out of the earth, all my company declined it. I told them, if they would stay for me, I would go alone. They promised they would. So I alighted and prepared to go up, when one of them offered to go up with me.

Having given our horses to our guides, who
stayed

stayed with the rest of our company, we ventured forward, resolving to reach the top, and in a short time saw a large flight of crows and vultures, that had their nest in the top of the mountain. Having ascended about half a league, we felt the ground shake under us, and heard a terrible noise in the bowels of the earth, just as if it was going to burst open. At the same time there appeared on all sides chinks, out of which issued bluish flames, with a strong suffocating smell. This made us turn back, for fear of being burnt to ashes. But we had scarce proceeded thirty yards back, before a black cloud of smoke ascended out of the mountain, obscured the light of the sun, and covered us so thick, that we could not see each other. Our fears increased every step we took; for behind us came flames of fire, with showers of ashes and pumice stones, which fell as thick as hail. This dreadful storm was attended with horrible noises, and we expected every moment, the earth would open and swallow us up. This added wings to our flight, so that in a quarter of an hour we got to the bottom of the mountain.

12. There are volcanos likewise in many of the American islands: and a very eminent one in Guadaloupe. The summit of this constantly emits smoke, and sometimes flames. It rises very high, in the form of a cone, above the chain of mountains, that occupy the center of the island. Near the foot of it are three springs, the waters of which are so hot as to boil eggs in three minutes. The neighbouring ground smokes and is full of brown earth, like the dross of iron. But the chief place where the smoke issues out, is higher up, at the foot of a steep bank, about fifty yards in breadth.

Here

Here no grass is to be seen; nothing but sulphur and calcined earth. The ground is full of deep cracks, which emit much smoke, and where you may hear the sulphur boil. But the stench of it is intolerable. The ground is loose, so that you may thrust a cane up to the head. And when you draw it up, it will be as hot as if you had plunged it into slaking lime.

On the plain top of the hill is another funnel, that opened some years since, and emits nothing but smoke. Here are abundance of large and deep chinks, which doubtless burned in former times. In the middle of this plain is a very deep abyfs. It is said there was once a great earthquake in the island, and that the Brimstone Hill (so they call it) then took fire. It was probably then this abyfs was opened. It is between two crags that rise above the mountain, and on the north side answers to the great cleft, which goes down above a thousand feet perpendicular, is more than twenty feet broad, and penetrates above an hundred paces in the flat. So that in this place the mountain is fairly split, from the top down to the basis of the cone.

On this plain you may see the clouds gather below, and hear the thunder rumble under your feet. The great cavern is under the cleft, and was doubtless formed by the same earthquake that split the mountain into two parts nearly equal. The parting goes north and south. To the north is the cleft and cavern, in the middle the abyfs, and to the south the burning gulph. The cavern is above twenty-five feet wide, as much in height, and about sixty paces deep. Within this is a second cave, about sixty feet in length, as much in breadth, and forty in height. Here the heat

is moderate: but there is a third cave within this, where it is so hot, that a torch will give no light therein, and a man can scarce fetch breath. Yet on the left is a great hollow, which is sufficiently cool. And the space of one fathom makes the difference. It seems strange, that in the same cave, three hundred feet under ground, it should be so hot on one side, and so cool on the other. Perhaps the cool side has some vent into the great cleft, and receives fresh air thereby.

13. Another surprising eminence, which may be ranked among burning mountains, is the Pike of Teneriffe. On the summit of it is an hollow twelve or fourteen feet deep: the sides sloping down to the bottom, form a cavity like a truncated cone, with its base uppermost. This cavity is nearly circular, about forty fathoms across. The ground is very hot, and from near twenty veins, issues a smoke of a strong sulphureous smell. The whole soil seems powdered with brimstone, which forms a beautifully coloured surface. Almost all the stones thereabouts are of a greenish colour, sparkling with a yellow, like gold. On the middle of one of the rocks is an hole, about two inches in diameter. Hence proceeds a noise like that of a great body of liquors boiling very strongly. And so hot a steam comes from it, as will burn the hand, even at a quarter of a yard's distance.

A small part of the sugar-loaf is white like lime; another small part is covered with salt. But the far greatest part is covered with snow, almost throughout the year.

The accounts given of its height are exceeding various. But a gentleman some years ago, who measured

measured it exactly, found the perpendicular height to be two thousand, five hundred and sixty six fathoms.

14. When it happens that any inflammable substance takes fire in the caverns of the earth, the air contained therein is rarefied and exploded with an immense force. Hereby not only the arch which covers it, but the whole body of incumbent earth is shaken. And this is one species of earthquakes. In this case, the deeper the cavern is, and the larger the quantity of matter which takes fire, the more extensive and the more violent the earthquake. If the cavern is near the surface of the earth, the fire often issues out of it: and the lower parts being eaten away, the ground sinks in, and swallows up houses or whole cities.

But, to consider this point a little more minutely. As some earthquakes are owing to fire, so are some to air, others to water, and others to earth itself. 1. The earth itself may be the occasion of its own shaking, when the root or basis of some large mass being worn away, that mass sinks in by its own weight, and causes a concussion of all the neighbouring parts. 2. Subterraneous waters wash away the foundations of hills, and eat far under the earth. By this means many earthquakes have been occasioned, and whole cities swallowed up. This was undoubtedly the cause of the great earthquake at Port Royal, and of that which swallowed up Lima. 3. Air pent up in the bowels of the earth, if it be at any time rarefied and expanded, will struggle for vent with incredible force, and thereby both shake and tear the earth. 4. But the usual cause of the most violent earthquakes is sulphur, or some other inflammable matter, taking fire in the cavities of the earth, and bursting through whatever opposes.

There are scarce any countries that are much subject to earthquakes, which have not some burning mountain. And whenever any earthquake happens, this is constantly in flames. Indeed were it not that these vents thus disgorge the fire, it would make far greater havock than it does ; probably it would make the whole country for a vast space round quite uninhabitable. Yea, so beneficial are these, that we do not want instances of countries frequently annoyed by earthquakes, which upon the breaking out of a volcano, have been wholly delivered from them.

Perhaps what causes most earthquakes of this kind is the Pyrites, or Iron-stone, which will take fire of itself. The earth, we know, abounds in cavities, which are at certain times full of inflammable vapours. This the damps in mines shew, which being fired, do every thing as in an earthquake, only in a less degree. And the Pyrites only, of all known minerals, yields this inflammable vapour. Nor is any mineral or ore whatever, sulphureous, but what is more or less mixed with the Pyrites. But probably the Pyrites of the burning mountains, is more sulphureous than ours. It is likewise in far greater quantities in all the countries round the Mediterranean than in England: a plain reason why earthquakes are so much more frequent and more violent there.

An artificial earthquake may be made thus. Add twenty pounds of sulphur to twenty of iron-filings. Mix and temper these with water, so as to form a mass of the consistence of a firm paste. Bury this three or four feet under ground. In six or seven hours time, the earth will begin to tremble, crack and smoke, and fire and flame will burst through. So that there only wants a sufficient

cient quantity of this matter, to produce a true *Ætna*. If it were supposed to burst out under the sea, it might occasion a new island.

To explain this point a little farther. This globe of earth is bored through with infinite cavities, which branching out like the veins, arteries, and nerves in our bodies, pass under the very bottom of the sea. Some of them serve to convey water, others a more unctuous substance, others an igneous matter, that gives motion to the whole frame.

Thus the exterior sea communicates with the inmost abyfs, and passes to the roots of the hills and mountains. Mean time a constant air or wind forces the water into the dark caverns, and receives and keeps alive a perpetual fire.

Have we not indubitable examples of these things? Does not the vast river *Volga*, pour such a quantity of water into the *Caspian*, within the space of one year, as would be sufficient, were there not some invisible out-let, to cover the whole earth. This invisible out-let is an huge cavern, that passes under *Mount Caucasus* into the *Euxine* sea. Hereby the waters of the one sea, discharge themselves into the other. And the whole kingdoms of *Georgia* and *Mengrelia*, are as it were a bridge over those subterraneous waters.

When the *Caspian* sea has been, on occasion of winds, too much emptied into the *Euxine*, it is replenished from the *Persian Gulph*, which is a kind of reservoir for it. And the subterraneous communication between the *Red Sea* and the *Mediterranean* is now out of all dispute.

And how many instances of this have we in rivers? So late Geographers assure us, that the river *Niger* in *Africa* is derived from the river *Nile*, under the mighty chain of the mountains of *Nubia*:

Nubia: on the western side of which mountains, it takes the name of Niger, and continues its course into the Atlantic ocean. So the vast and deep cave in mount Taurus, receives the Tigris, and gives it a passage to the other side. The same river afterward hides itself under ground, for near twelve miles, and then breaking out again, disembogues into the Euphrates, near Babylon.

To come nearer home; the Guadiana, that runs between Spain and Portugal, runs thirty-two miles under ground. Yea, in our own country, the Mole in Surry, falls into the ground near Boxhill, and rises again at a considerable distance.

Hence we may safely collect that the earth is filled with subterraneous aqueducts and caverns, full of air and vapour and copious exhalations from all sorts of minerals, as well as water.

Besides these cavities, there are mountains whose bowels are in a continual flame. And their belching out ashes, smoke, broken rocks and minerals, argue vast vacuities, and huge magazines of combustible matter, which are lodged therein. In the chain of mountains called the Andes in America, there are no less than fifteen volcanos, by whose burnings, caverns as big as whole kingdoms are made, and receive the cata-racts of mighty rivers. And not only here, but over all the earth, there are so many channels, clefts, and caverns, that we do not know, when or where we stand upon good ground. Indeed it might amaze men of a stout heart, could they see into the world beneath their feet, view the dark recesses of nature, and observe the strongest build-ings stand upon an immense vault, at the bottom of which runs an unfathomable sea, and whose upper hollows, are filled with stagnating air and
the

the expirations of sulphureous and bituminous matter.

Therefore as there are no large tracts of land, without volcanos and sulphureous caverns, from which branching into smaller pipes, the subterraneous heat is conveyed throughout the earth: so no country can promise itself an entire immunity from earthquakes: even were there no other cause of these dreadful events, but subterraneous fires. Especially, when it is considered, that the earth is in one part impregnated with sulphur, in others with nitre, allum, vitriol, mercury, bitumen, oker and chalks. For if an artificial powder, made only of nitre, sulphur and charcoal has so wonderful effects, what force must that combustible matter have, which arises from sulphur, nitre, sal-almoniac, bitumen, gold, copper, iron, arsenic, mercury, and other metallic and mineral spirits, with which the womb of the earth abounds, when the subterraneous fires break through into the hollow vaults, where these are reposit by the God of nature? Then, according to the copiousness of these combustibles, and the more or less firmness of the super-incumbent earth, these fires cause tremblings and concussions, or violent eruptions: and perhaps open wide and deep gulphs, wherein whole cities, yea mountains are swallowed up.

Many such instances occur in history. Pliny tells us, that in his own time, the Mountain Cymbotus, with the town of Eurites, which stood on its side, were totally swallowed up. He records the like of the city of Tantelis in Magnesia, and after it of the mountain Sopelus, both absorbed by a violent opening of the earth, so that no trace of either remained.

remained. Galanis and Garnatus, towns once famous in Phœnicia, are recorded to have met the same fate. Yea, the vast promontory called Phlegium in Ethiopia, after a violent earthquake in the night, was not to be seen in the morning, the earth having swallowed it up and closed over it.

Like instances we have of later date. The mountain Picus, in one of the Molucca's, was so high, that it appeared at a vast distance, and served as a land mark to sailors. But during an earthquake in the isle, the mountain in an instant sunk into the bowels of the earth: and no token of it remained, but a vast lake of water. The like happened in the mountainous parts of China, in 1556: when a whole province, with all its towns, cities, and inhabitants was absorbed in a moment; an immense lake of water, remaining in its place, even to this day.

In the year 1646, during the terrible earthquake in the kingdom of Chili, several whole mountains of the Andes one after another, were wholly absorbed in the earth. Probably many lakes of whose beginning we have no account, were occasioned by the like absorptions.

The greatest earthquake we find in antiquity is that mentioned by Pliny, in which twelve cities in Asia Minor were swallowed up in one night. But one of those most particularly described in history is that of the year 1693. It extended to a circumference of two thousand six hundred leagues, chiefly affecting the sea coasts and great rivers. Its motions were so rapid, that those who lay at their length were tossed from side to side

as upon a rolling billow. The walls were dashed from their foundations, and no less than fifty four cities, with an incredible number of villages, were either destroyed, or greatly damaged. The city of Catanea, in particular, was utterly overthrown. A traveller who was on his way thither, at the distance of some miles perceived a black cloud hanging near the place. The sea all of a sudden began to roar: Mount *Ætna* to send forth great spires of flame; and soon after a shock ensued, with a noise, as if all the artillery in the world had been at once discharged. Our traveller being obliged to alight instantly, felt himself raised a foot from the ground, and turning his eyes to the city, saw nothing but a thick cloud of dust in the air. Although the shock did not continue above three minutes, yet near nineteen thousand of the inhabitants of Sicily perished in the ruins.

The following account of a dreadful earthquake at Calabria in 1638, is related by the celebrated Father Kircher, as it happened while he was on his journey to Mount *Ætna*.

“ Having hired a boat in company with four more, we launched on the 24th of March from the harbour of Messina, and arrived the same day at the promontory of Pelorus. Our destination was for the city of Euphæmia in Calabria. But though we often put to sea, we were as often driven back, At length however, we ventured forward. Proceeding onward, and turning my eyes to *Ætna*, I saw it cast forth large volumes of smoke, which entirely covered the whole island. This together with the dreadful noise, filled me with apprehension. The sea itself began to wear
a very

a very unusual appearance, covered all over with bubbles. My surprize was increased by the calmness of the weather. I therefore warned my companions, that an earthquake was approaching, and making for the shore with all possible speed we landed at Tropæa. But we had scarce arrived at the Jesuit's College in that city, when our ears were stunned with a horrid sound resembling that of an infinite number of chariots driven fiercely forward, the wheels rattling, and the thongs cracking. Soon after, the whole tract upon which we stood, seemed to vibrate, as if we were in the scale of a balance that continued wavering. This soon grew more violent, and being no longer able to keep my legs, I was thrown prostrate upon the ground. In the mean time, the universal ruin round me, redoubled my amazement. The crash of falling houses, the tottering of towers, and the groans of the dying, all contributed to raise my terror. On every side of me, I saw nothing but a scene of ruin, danger threatening wherever I could fly. I recommended myself to God as my last refuge. At that hour, O how vain was every sublunary happiness! Wealth, honour, empire, wisdom, all mere useless sounds, and as empty as the bubbles on the deep. Just standing on the threshold of eternity. Nothing but God was my pleasure, and the nearer I approached, I only loved him the more. After some time, however, I resolved to venture for safety, and running as fast as I could, reached the shore. I did not search long, till I found the boat in which I had landed and my companions also. Our meeting was all silence, and a gloomy dread of impending terrors.

“ Leaving this seat of desolation, we prosecuted
our

our voyage, and the next day landed at Rochetta, although the earth still continued in violent agitations. But we were scarce arrived at our inn, when we were obliged to return to the boat, and in about half an hour, we saw the greatest part of the town, and the inn at which we had set up, dashed to the ground, and burying all its inhabitants beneath its ruins. Proceeding onward in our little vessel, finding no safety at land, and yet having but a very dangerous continuance at sea, we at length landed at Lapizium, a castle midway between Trapæa and Euphæmia. Here wherever I turned my eyes, nothing but scenes of ruin and horror appeared; towns and castles levelled to the ground: Strombalo, though at sixty miles distance, belching forth flames in an unusual manner. But my attention was quickly turned to nearer danger. The rumbling sound of an earthquake alarmed us. It every moment seemed to grow louder, and to approach more near. The place on which we stood, now began to shake most dreadfully, so that being unable to stand, my companions and I caught hold of the shrubs near us, and supported ourselves in that manner.

“ After some time this shock ceasing, we stood up in order to go to Euphæmia, that lay within sight. In the mean time, I turned my eyes towards the city, but could see only a dark cloud resting upon the place. This the more surprized us, as the weather was so serene. We waited till the cloud was part away, then looking for the city, it was totally sunk. Nothing but a putrid lake was seen where it stood. We looked about for some one that could tell us the sad catastrophe, but could see none. All was become a melancholy solitude, a scene of hideous desolation.

Such

Such was the fate of the city of Euphæmia. And as we continued our melancholy course along the shore, the whole coast for the space of two hundred miles presented nothing but the remains of cities. Proceeding thus along, we at length ended our distressful voyage, by arriving at Naples."

15. Of the great Earthquake at Port-royal in Jamaica, an eye-witness writes thus. It happened on July 7, 1692, just before noon, and in the space of two minutes, shook down and drowned nine tenths of the town. The houses sunk outright thirty or forty fathom. The earth opened and swallowed up the people, in one street, and threw them up in another: some rose in the middle of the harbour. While the houses on one side of a street were swallowed up, those on the other side were thrown on heaps. The sand in the street, rising like waves in the sea, lifted up every one that stood upon it. Then suddenly sinking into pits, the water broke out, and rolled them over and over. Sloops and ships in the harbour were overset, and lost: the Swan Frigate was driven over the tops of many houses. All this was attended with a hollow rumbling noise. In less than a minute, three quarters of the houses, with their inhabitants, were all sunk under water: and the little part which remained was no better than an heap of rubbish. The shock threw people down on their knees, or their faces, as they ran about to look for shelter. Several houses which were left standing, were removed some yards out of their places. One whole street was made twice as broad as before. In many places the earth cracked, opened and shut, with a motion quick and fast. And two or three hundred of these openings

might

might be seen at a time. In some of these people were swallowed up, in others caught by the middle and pressed to death. In others the heads of men only appeared, in which condition dogs came and ate them. Out of some of these openings, whole rivers of water spouted up a prodigious height: and out of all the wells the water flew, with a surprizing violence. The whole was attended with a noisome stench, and the noise of falling mountains at a distance, while the sky in a minute's time turned dull and reddish, like a glowing oven. And yet more houses were left standing at Port-royal, than in all the island beside. Scarce a planter's house, or sugar work was left throughout all Jamaica. A great part of them was swallowed up, frequently houses, people and trees at one gap, in the room of which there afterwards appeared a large pool of water. This when dried up, discovered nothing but sand, without any mark that house or tree had been there. Two thousand people lost their lives: had it been in the night, few would have escaped. A thousand acres of land were sunk: one plantation was removed half a mile from its place. Yet the shocks were most violent among the mountains. Not far from Yall-house, part of a mountain, after it had made several leaps, overwhelmed a whole family, and great part of a plantation, though a mile distant. A large mountain, near Port Morant, about a day's journey over, was quite swallowed up, and in the place where it stood, remained a lake, four or five leagues over. Vast pieces of mountains with all the trees thereon, falling together in a confused manner, stopped up most of the rivers, till swelling abroad, they made themselves new channels, tearing up every thing that opposed their

their passage, carrying with them into the sea, such prodigious quantities of timber that they seemed like moving islands. In Liquania the sea, retiring from the land, left the ground dry for two or three hundred yards. But it returned in a minute or two, and overflowed a great part of the shore. Those who escaped from the town, got on board the ships in the harbour, where many continued two months: the shocks all the time being so violent, that they durst not come on shore. The noisome vapours occasioned a general sickness, which swept away three thousand of those that were left.

The following account of this memorable event is given by the Rector of Port-royal.

On Wednesday, June 7, I had been reading prayers, (which I have read every day since I came to Port-Royal, to keep up some shew of religion among a most ungodly people) and was gone to the President of the Council. We had scarce dined, when I felt the ground heave and roll under me. I said, "Sir, what is this?" He replied composedly, "It is an earthquake. Be not afraid; it will soon be over." But it increased more and more: and presently we heard the church and the tower fall. Upon this we ran to save ourselves; I quickly lost him, and ran toward Morgan's Fort; as that was a wide open place, and secure from the falling houses. As I ran, I saw the earth open, and swallow up multitudes of people, and the sea mounting over the fortifications. I then laid aside all thought of escape, and went homeward to meet death in as good a posture as I could. I was forced to go through two or three narrow streets, the houses fell

on each side of me, Some bricks came rolling over my shoes, but none hurt me. When I came to my lodging, I found all things in the same order that I left them. I went to the balcony, and saw that no houses in our street were fallen. The people seeing me, cried to me, to come and pray with them. When I came into the street, every one laid hold of my cloaths and embraced me. I desired them to kneel down in a ring, and prayed with them near an hour, till I was almost spent, between the exercise, and the heat of the sun. They then brought me a chair, the earth working all the time, like the rolling of the sea, insomuch that sometimes while I was at prayers, I could hardly keep on my knees. By the time I had been half an hour longer with them, in setting their sins before them, and exhorting them to repentance, some merchants came, and desired me to go on board one of the ships in the harbour. From the top of some houses, which lay level with the water, I got into a boat, and went on board the Siam Merchant. The day when this happened was exceeding clear, and afforded no suspicion of evil. But about half an hour past eleven, in less than three minutes, Port Royal, one of the fairest towns in the English plantations, was shattered in pieces, and left a dreadful monument of the justice of God.

About ten years after the town was rebuilt, a terrible fire laid it in ashes. Yet they rebuilt it once more. But in the year 1722, an hurricane reduced it a third time to an heap of rubbish. Warned by these extraordinary calamities, which seemed to mark it out as a devoted spot, they removed the public offices from thence, and forbade any market to be held there for the future."

16. Lima in Peru contains about 60,000 persons. In 1747 an earthquake laid three fourths of the city level with the ground.

17. Callao, the Port of Lima, containing 3 or 4000 inhabitants was totally destroyed. Only one man escaped, and that by a very singular providence. He was going to strike the flag on the fort, that overlooked the harbour, when he saw the sea retire to a considerable distance, and then return, swelling mountains high. The inhabitants ran from their houses, in the utmost degree of terror and confusion. A cry for mercy arose from all parts: and immediately all was silent, the sea had quite overwhelmed the city, and buried it for ever in its bosom. But at the same time it drove a little boat to the side of the fort, into which the man leaped and was saved.

18. Perhaps we have not in history, many more remarkable deliverances than that of this good man. But more remarkable if possible, is the following deliverance, from a danger of a very different kind.

In the neighbourhood of Demonte, as one descends through the upper valley of Stura towards the middle of the mountain, there were some houses in a place called Bergemolletto, which on the 19th of March, in the morning (there being then a great deal of snow) were entirely overwhelmed by two vast bodies of snow, that tumbled down from the upper Alps. All the inhabitants were then in their houses, except one Joseph Rochia, a man of about 50. Two and twenty persons were buried under this mass of snow, which was sixty English feet in height. Many
men

men were ordered to give them assistance; but were not able to do them the least service. After five days, Joseph Rochia, got upon the snow, (with his son, and two brothers of his wife) to try if they could find the place under which his house and stable were buried; but they could not. However, the month of April proving very hot, and the snow beginning to melt, this unfortunate man was again encouraged to use his best endeavours. On the 24th, the snow was greatly diminished, and he conceived hopes of finding out his house by breaking the ice. He thrust down a long pole, but the evening coming on, he proceeded no farther. His wife's brother dreamed the same night, that his sister was still alive, and begged him to help her. He rose early in the morning, told his dream to Joseph and his neighbours, and went with them, to work upon the snow, where they made another opening, which led them to the house they searched for: but finding no dead bodies in its ruins, they sought for the stable, which was about 240 English feet distant, and having found it, they heard a cry of "help, my dear brother." Being greatly surprized as well as encouraged by these words, they laboured till they had made a large opening, through which the brother went down, where the sister with a feeble voice told him, "I have trusted always in God and you, that you would not forsake me." The other brother, and the husband then went down, and found still alive the wife about 45, the sister about 35, and a daughter about 13 years of age. These they raised on their shoulders to men above, who pulled them up, and carried them to a neighbouring house; they were unable to walk,

and so wasted, that they appeared like mere shadows.

Some days after the Intendant came to see them, and they gave him the account that follows. In the morning of the 19th of March, we were in the stable, with a boy six years old, and a girl about 13. In the same stable were six goats, one of which had brought forth two dead kids the evening before; there were also an ass and five or six fowls. We were sheltering ourselves in a corner of the stable, till the church-bell should ring, intending to attend the service. The wife wanting to go out of the stable to kindle a fire for her husband, then clearing away snow from the top of the house, she perceived a mass of snow breaking down towards the east, on which she went back into the stable, shut the door, and told her sister of it. In less than three minutes they heard the roof break over their heads, and also part of the ceiling of the stable. The sister advised her to get into the rack and manger, which she did very carefully. The ass was tied to the manger, but got loose by struggling; and though it did not break the manger, it threw down the little vessel which the sister took up, and used afterwards to hold the melted snow, which served them for drink. Very happily, the manger was under the main prop of the stable, and thereby resisted the weight of the snow. Their first care was to know what they had to eat; the sister had in her pockets fifteen chestnuts: the children said they had breakfasted, and should want no more that day. They remembered there were 30 or 40 loaves in a place near the stable, and endeavoured to get at them, but were not able, by reason of the snow. On this they called out for help

as loudly as they could, but no one heard them. The sister came again to the manger, after she had tried in vain to come at the loaves, gave two chestnuts to the wife, and eat two herself, and they drank some snow water. All this while the asses continued kicking, and the goats bleated very much, but soon after, they heard no more of them. Two of the goats however were left alive, and were near the manger, they felt them carefully, and knew by so doing, that one of them was big, and would kid about the middle of April; the other gave milk, wherewith they preserved their lives.

The women affirmed, that during all the time they were buried, they saw not one ray of light; nevertheless, for about twenty days, they had some notion of night and day: for when the fowls crowed, they imagined it was break of day, but at last the fowls died. The second day, being very hungry, they eat all the remaining chestnuts, and drank what milk the goat yielded, which for the first days was near two pounds a day, but the quantity decreased gradually. The third day, being very hungry, they again endeavoured to get to the place where the loaves were, but they could not penetrate to it. They then resolved to take all possible care to feed the goats, as very fortunately over the ceiling of the stable, and just above the manger, there was an hay-loft with a hole, through which the hay was put down into the rack. This opening was near the sister, who pulled down the hay, and gave it to the goats, as long as she could reach it, which when she could no longer do, the goats climbed upon her shoulders, and reached it themselves. On the sixth day

the boy sickened, complaining of violent pains in the stomach for six days, on the last of which he desired his mother, who all this time had held him in her lap, to lay him at his length in the manger. She did so, and taking him by the hand, felt it was very cold: she then put her hand to his mouth, and finding it likewise very cold, she gave him a little milk; the boy cried, "O my father in the snow! Oh! father! father! and expired."

The mother told the sister, the boy was dead, and then laid him in the manger where the sister was. In the mean while the milk given by the goat diminished daily. The fowls being dead, they could no longer distinguish night and day; but according to their calculation the time was near, when the other goat should kid, which as they computed would happen about the middle of April. At length they found the goat was kidding by its cries, the sister helped it; they killed the kid to save the milk for their own subsistence. And now they knew it was the middle of April. Whenever they called this goat, it would come and lick their face and hands, and gave them every day two pounds of milk, for which they still bear a great affection to it.

During all this time, hunger gave them but very little uneasiness, except on the first five or six days. Their greatest pain was from the extreme coldness of the melted snow-water, which fell on them; from the stench of the dead ass, dead goat, and fowls; but more than all from the uneasy posture they were obliged to continue in. For though the place in which they were buried was twelve English feet long, eight wide, and five high, the manger in which they sat squatting
against

against the wall, was no more than three feet four inches broad.

19. May we not impute to earthquakes, those huge cavities in the earth, which are found in several parts of England? Such is Pooles-Hole about half a mile from Buxton, in Derbyshire, said to have been the refuge of one Poole, a noted robber. It is at the foot of a mountain: its entrance is low and narrow; but it presently opens into a broad and lofty concavity, of above a mile in length. The water dropping from the roof, congeals into a kind of chrystal, and forms a thousand surprising figures. Here is also a large, clear stone, resembling alabaster, which the Queen of Scots, when here, called her pillar, and it still goes by that name. Along the middle a stream of water falls among the rocks, which loudly echoes through the vault. The most surprising thing is, the height of the arch, and the spangled roof resembling fret-work. And indeed the drops of water which petrifying, as they fall, form icicles, resembling chrystal above, and pyramids hardened into stone below, have a surprising effect from the light of the candles: the hanging drops dazzling the eyes, as if this mighty arch was covered with diamonds.

Elden-hole is a frightful chasm in the middle of a field, fifty or sixty feet long, and about twenty broad. But how deep it is, could never be discovered, notwithstanding all the attempts that have been made. Mr. Cotton endeavoured to fathom it with a line of sixteen hundred yards; but in vain. Some suppose these to have been passages, whereby the waters of the deluge, returned from the surface of the earth to the great abyfs.

There is another effect of subterraneous fires, which has been generally imputed to quite different causes. The Giant's Causeway in Ireland, and all other strong concretions of the same kind, where pillars are formed by pentagon, hexagon, or mutangular stones, placed one upon another, they are commonly supposed to be formed by a deposition of stony matter from an aqueous fluid. On the contrary it is evident from various considerations, respecting their structure and other phenomena, that they are concretions of a peculiar kind, generated by an igneous fluid. They are peculiar to vulcanic countries, and differ in every respect from the chrystals produced by the slow and successive precipitation of the stony particles contained in water. Their formation is owing to an intrinsic principle of organization, operating on an ignified fluid: on the concretion of which that principle may be supposed to have operated simultaneously in a large mass, and to have produced these bodies in the same manner as a linget of metal concretes at once in the mold.

In Persia there is a subterraneous fire of a very harmless nature. It rises out of the ground, about twenty miles from Baku, and three from the Caspian sea. The ground is rocky, but has a shallow covering of earth. If this be any where scraped off, and fire applied to the place, it catches. fire immediately, and burns without diminution, nor ever goes out, unless you throw cold earth over it, by which it is easily extinguished. A piece of ground, about two English miles in extent, has this wonderful property. In many parts of it there is a continual flame: the chief is in an hole about four feet deep and fourteen in diameter.

This

This is said to have burned many thousand years. They burn stones into lime, by filling a hole in the ground with them, and then putting a lighted candle into the hole. The fire immediately kindles, and in about three days burns the stones sufficiently.

It is remarkable, that this flame, how great so ever it be, gives neither smoke nor smell. There is much naphtha all about the place, though not just where the fire is.

Doubtless an inflammable vapour issues in abundance out of the ground in this place. Something of the same kind is found between Bologna and Florence, on the side of one of the Appenines. On a spot of ground three or four miles diameter, there is a constant eruption of fire. The flame rises very high; yet without noise, smoke, or smell. In great rains it sometimes intermits, but afterwards burns with the greater vigour. There are three other such fires on the same mountains. Probably they rise from the veins of bitumen.

20. A late ingenious writer ascribes all earthquakes to the same cause, Electricity. The impressions, says he, they make on land and water, to the greatest distance, is instantaneous. This can only be effected by Electricity. In the late earthquake the concussion was felt through the space of an hundred miles in length, and forty in breadth, at the same instant. Now what could throw a tract of land, of four thousand square miles in surface, into such an agitation in a moment? No natural power is equal to this, but that of Electricity, which alone acknowledges no bounds, neither any sensible transition of time.

The little damage done by most earthquakes, is another argument, for their being occasioned, by a simple vibration of the earth, through an electric shock. This vibration on the water, meeting with the solid bottoms of ships, occasions that thump which is felt by them. That this shakes millions of ordinary houses, and yet not one of them falls, is a farther proof, that it is not a convulsion in the bowels of the earth, but an uniform vibration, like what we occasion in a glass, by rubbing our finger on the edge: which yet may be brought to such a pitch, as to break the glass in pieces, by an electric repulsion of its parts.

There can be little doubt, but some earthquakes are owing to electricity; but many more are owing to other causes: those of Callao, Lima, Port Royal, for instance, were unquestionably owing to water: those in the neighbourhood of *Ætna* and *Vesuvius*, with those in the East-Indies, to lakes of fire. The grand fault is therefore the ascribing them either to electricity, or any one cause, exclusive of the rest: whereas some are owing to each of these causes: some to several of them acting conjointly.

21. We have inflammable vapours in England, in three or four different places.

One who accurately observed it, gives the following particular account of a burning well.

“ In the latter end of February, I went to see a spring in the road, which leads from Wigan to Warrington. When we came to it, and applied a lighted candle to the surface of the water, there was suddenly a large and vigorous flame produced. But having filled a cup with water at the flaming place, and held a lighted candle to it, it
went

went out. Yet the water at that place boiled like water over a fire: though when I put my hand into it, it did not feel so much as warm. This boiling seems to proceed from some sulphureous fumes, the spring being not above forty yards from a coal-pit, and all the country for many miles round being underlaid with coal.

When the water was drained away, I applied the candle to the surface of the earth where the water burned before. The fumes took fire and burnt very bright and vigorous, the flame ascending a foot and an half from the ground: and the basis of it was as broad as a man's hat at the brims. It was not discoloured like that of sulphur, nor had any scent. I ordered a bucket of water to be poured on the fire, and it was immediately quenched."

22. There was a spring of the same kind at Brosely, near Wenlock, in the county of Salop. It was discovered in June 1711, by a terrible noise in the night, which awaked several people in their beds, who desiring to know what it was, rose up, and coming to a boggy place under a little hill about two hundred yards from the Severn, perceived a mighty rumbling and shaking of the earth, and a little water boiling up through the grass. When they dug up some of the earth, the water flew up to a great height, and a candle that was in their hand, set the vapour on fire. There is now (viz. in 1711) an iron cistern round the spring, with a cover, having a hole in the middle of it. If you put a lighted candle to the hole, the water takes fire, and burns like spirits of wine. It burns as long as you keep the air from it; but if you take up the cover, it goes out. The heat of this fire exceeds that of common fire. Some

people, after they have set the water on fire, have put a kettle of water over the cistern, with a joint of meat in it. It was boiled much sooner than it could be, by any artificial fire. If you put wood or even green boughs upon it, it presently consumes them to ashes. The water of itself feels as cold as any common water. Nay, if you put your hand into it as soon as the fire is out, it feels as cold as if there had been no fire near it. But it still continues boiling up, with a considerable noise.

But this well was lost for many years. The poor man in whose land it was, missing the profit he used to have by shewing it, used all his endeavours to find it again: and in May 1744, hearing a rumbling noise under ground, a little nearer the river than the former well was, he lighted upon it again. For five or six feet deep, it is above six feet wide. Within this is a smaller hole, of like depth, dug in the clay, in the bottom of which is a cylindric earthen vessel, four or five inches diameter, having the bottom taken off, and the sides fixed in the clay. Within the pot is brown water, thick as puddle, continually forced up with a violent motion and a hollow noise, rising and falling by turns, five or six inches. Upon putting a candle at the end of a stick, within a quarter of a yard, it took fire, darting and flashing in a violent manner, about half a yard high, much like spirits in a lamp, but with a greater agitation. The man said it had made a tea-kettle boil in nine minutes, and that it would burn forty-eight hours without any sensible diminution. It was extinguished by putting a wet mop upon it. And still the water felt very cold.

The well lies about thirty yards from the Severn, which in that place, and for some miles above and below, runs in a vale full an hundred yards perpendicular below the level of the country on either side. But the well is now lost again, the water being drawn off by a coal-pit.

23. There is a fire of the same kind at Pietra Mala, a village on the Appenines. The flame is extremely bright, covers a surface of three yards by two, and usually rises about four feet. After great rains or snows, the whole bare patch, about nine yards diameter, flames. The gravel out of which it rises, at a very little depth, is quite cold. There are four of these fires in the neighbourhood: the middle of the ground whence one of them rises, is a little hollowed, and has in it a puddle of water, through which there are strong ebullitions of air. This air will not take fire; but that which rises through the wet and cold gravel, flames briskly.

In Dauphiny and some other parts of France, the surface of several springs take fire in the same manner on the approach of a candle. Sulphureous vapours undoubtedly exhale from the waters: as is the case in the famous Grotto del Cani.

This lies on the side of a little hill, between Naples and Pozzoli. The sides of it are cut perpendicular in the earth. It is about three feet wide; near twelve feet long; five or six feet high at the entrance, and less than three at the farther end.

The ground slopes a little from this end to the mouth, and more from thence to the road. If you stand a few steps without, and stoop so as to

have your eye nearly on a level with the ground of the grotto, you may see a vapour within, like that which appears over a chafing-dish of red-hot coals, only that it is more sluggish, and does not rise above five or six inches high. Its surface more distinctly terminated than that of other vapours, balances visibly under the air, as if unwilling to mix with it.

The ground of the grotto is always moist ; and so are the sides to the height of ten inches. Yet this never increases so as to form any drops. While you stand upright, you remark nothing more, than a slight earthy smell, common in all subterraneous places which are kept shut. But if you put down your hand, within ten inches of the ground, it feels as if you put it into the steam of boiling water. Yet your hand contracts neither smell nor taste. A vapour similar to that in the grotto, rises also from the ground without. But it is weaker, and does not rise so high. This partly spreads itself from the cavern, partly exhales from the earth.

A lighted flambeau thrust into the vapour, presently goes out ; yet without any noise or hissing. The thick smoke which appears immediately after its extinction, remains floating on the vapour, and being lighter than it, but heavier than the air above it, spreads between both. Indeed common smoke is lighter than air : but that impregnated with the vapour is heavier.

If a young vigorous dog be held down within the vapour, he at first struggles, pants, snorts, and rattles in the throat. But in three minutes he lies as dead. Carry him into the open air, and he draws in long draughts, as one recovering from a fit, and in two minutes gets upon his legs,

legs, and seems to ail nothing. A cock having his head plunged into the vapour, was suffocated all at once beyond recovery. Frogs are stupified by it in three or four minutes: yet though they have laid in it a quarter of an hour, soon recover when placed in the open air. Large flies, beetles and butterflies, were longer without giving signs of their suffering, and longer in recovering. A toad resisted the vapour near half an hour, a lizard above an hour and a quarter. And a large grasshopper stirred in the vapour, after being more than two hours in it.

An English gentleman kneeled down in the grotto, and leaning on his hands, bowed his face to within two or three inches of the ground, holding his breath, keeping his eyes open, and his tongue a little out of his mouth. He remained thus three or four seconds, without any painful impression, or any sort of taste on his tongue. And hence it manifestly appeared, that this is not a poisonous vapour.

He afterward advanced his face to the surface of the vapour, and took in breath gently. He was sensible of something suffocating, just like the air of a hot and moist stove. Likewise he felt a slight acrimony in the throat and nose, which made him cough and sneeze: but no head-ach, no sickness at stomach, nor any other inconvenience.

It is clear then upon the whole, that animals die in this vapour, not as poisoned, but rather as drowned, in a fluid not capable of supplying the place of the air, which is necessary for respiration, and equally necessary to sustain fire, as the flame of a lighted flambeau.

24. A fire of a still stranger nature appeared in Wales, about Christmas, 1693. A fiery vapour came from the sea, and moved up and down for many weeks. It set on fire sixteen ricks of hay, at Harlech, in Merionethshire, and two barns, and annoyed the country, as well by poisoning the grafs, as firing the hay. It was a blue, weak flame, and did no harm to the men who tried to save the hay, though they ventured even to touch it. An intelligent person who lived near Harlech, informed his friend some time after, " The fire still continues there. It comes over a part of the sea, from a marshy place in Carnarvonshire, eight or nine miles off. The grafs over which it moves kills all manner of cattle that feed upon it, sheep, goats, swine, cows and horses. But what is very remarkable is, that any great noise, as beating a drum or sounding an horn, effectually repells it from any house, or barn, or stack of hay."

25. A much stranger flame than that which issues out of the earth, is that which issues out of the stomach of animals. The anatomical lecturer at Pisa in the year 1597, happening to hold a lighted candle near the subject he was dissecting, on a sudden set on fire the vapours that came out of the stomach he had just opened. In the same year, as Dr. Ruisch, then anatomy professor at Pisa, was dissecting a woman, a student lighting him with a candle, he had no sooner opened the stomach, than there issued out a yellow greenish flame. A like thing happened some years after at Lyons, in dissecting a woman. Her stomach was no sooner opened, than a considerable flame burst out and filled the place. But this is not so much to be wondered at, since the experiments made by Dr. Vulpari, anatomical professor at Bologna

logna. He affirms, any one may see, issuing from the stomach of an animal, a matter that burns like spirits of wine, if the upper and lower orifices are bound fast with a very strong thread. The stomach thus tied must be cut, above and under the ligature, and afterwards pressed with both hands, so as to make all that it contains, pass to one side. This will produce a swelling in that part, which must be held with the left hand to hinder its escaping. A candle then being held about half an inch from the stomach, let it be suddenly opened by the right hand, and a bluish flame will immediately gush out, which will sometimes last a minute. The same way flame may be brought forth from the intestines also.

Nor is it from carcases only that flames have issued. This has been the case with live persons likewise. Bartholine relates, that a Polish Cavalier, having drank a quantity of brandy died in a little space, after an eruption of a flame through his mouth. He relates also the case of three others, who after drinking much brandy experienced the same symptom. Two presently died; the third escaped by immediately drinking cold water. Still more astonishing is the case of a woman at Paris, who used to drink brandy to excess. She was one night reduced to ashes by a fire from within, all but her head and the ends of her fingers. In like manner Cornelia Bandi, an aged lady of unblemished life, near Cesena in Romagna, in 1731, retired in the evening into her chamber; and in the morning was found in the middle of the room, reduced to ashes, all except her face, skull, three fingers and her legs, which remained entire, with her shoes and stockings. The ashes were light: the floor was smeared with a gross, stinking moisture, and the walls
and

and furniture covered with a moist foot, which had stained all the linen in the chest.

Perhaps a larger account of so remarkable an incident will not be unacceptable to the curious reader.

The countess Cornelia Bandi, in the sixty-second year of her age, was all day, as well as usual. When she was in bed, she passed two or three hours in talking with her maid; then she fell asleep. The maid going into her chamber in the morning, saw two feet distant from the bed, an heap of ashes, and two legs with the stockings on. Between them was part of the head; but the brains, half the skull, and the whole chin were burnt to ashes. The ashes, when taken up, left in the hand a greasy and stinking moisture. The bed received no damage; the cloaths were raised on one side, as by a person rising from it.

Doubtless the fire was kindled within her by the juices and fermentations in the stomach, acting on the many combustible matters, which abound in living bodies, for the uses of life. These in sleep, by a full respiration, are put into a stronger motion, and consequently are more apt to take fire.

Borelli observes, That such accidents often happened, to great drinkers of wine and brandy. Such flames would frequently rise in us, if the natural moisture did not prevent.

Undoubtedly she was burnt standing; hence her skull was fallen between her legs, and the back part of her head was damaged more than the fore part, partly because of her hair, partly because in the face, there were many places, out of which the flames might pass.

An instance of the same kind occurred at Christ Church in Hampshire, on June 26, 1613. One John Hitchell, a carpenter of that parish, having ended his day's work, came home and went to rest with his wife. Her mother being frightened in her sleep, called to them for help. None answering, she started up and waked her daughter, who found her husband dead by her side. She dragged him out of the bed into the street; but the heat then forced her to let him go. He lay burning there for three days. Not that there was any appearance of fire outwardly, but only a smoke ascending from his carcase, till it was burnt to ashes: except only a small part of his bones, which were cast into a pit.

Grace Pett, was a fisherman's wife, of the parish of St. Clement's, in Ipswich, about sixty. She had a custom for several years of going down stairs every night, after she was undrest, to smoke a pipe. Her daughter, who lay with her, did not miss her till the morning, April 10, 1744, when going down stairs she found her mother's body extended over the hearth, with her legs on the deal floor, and appeared like a block of wood, burning with a glowing fire without flame. The neighbours coming in at her cries, found the trunk of the body in a manner burnt to ashes. It then appeared like an heap of charcoal, covered with white ashes, the head, arms, legs, and thighs were also much burnt. A child's cloaths, on one side of her, and a paper-skreen on the other, were untouched. The deal floor also on which her legs lay, was neither singed nor discoloured.

26. Almost as strange, though not attended with any ill consequence, was the following incident. In November, Mrs. Susanna Sewall, wife to major Sewall,

Sewall, in New England, observed a strange flashing of sparks in all the apparel she put off, which continued till Candlemas. In the company of many persons, she sent for several parts of her wearing apparel, and when they were shaken, sparks flew out, making a noise, much like bay-leaves thrown into the fire. One spark lit on major Sewall's thumb-nail, without any heat, and continued at least a minute before it went out. They caused Mrs. Sewall one day to put on her sister Digge's petticoat; and when she put it off at night, it sparkled as her own used to do.

27. There is no body but may be by fire converted into glass; not excepting gold itself. And this is the last effect of fire: no art can carry the change of a natural body any farther.

As to the nature and properties of it. 1. Common glass is an artificial compound of salt with sand or stones. 2. It is fusible by a strong fire, and when fused is tenacious and coherent. 3. It does not waste in the fire. 4. When melted it cleaves to iron. 5. When red hot it is fashionable into any shape, and capable of being blown into a hollowness, which no mineral is. 6. It is frangible when thin, fryable when cold, and transparent whether hot or cold. 7. It is flexible, elastic, and dissoluble by cold. It can be cut only by emery or a diamond. 9. It is not dissoluble by Aquafortis, Aqua Regia or Mercury. 10. Neither acids nor any thing else extract colour, taste, or any sensible quality from it. 11. It loses nothing either of its substance or of its weight, by the longest and most frequent use. 12. It is not capable of being calcined, neither of contracting rust.

But there is no property of glass more remarkable than its ductility. Glass-spinners draw threads
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of their brittle matter, melting over a lamp, with far more ease and expedition, than common spinners do those of flax or silk. These may be drawn fine as a hair, yea, as the thread of a spider's web, so as to wave with every wind. And the finer they are, the more flexible. If the ends of two such threads be knotted together, they may be drawn and bent till the space in the middle of the knot does not exceed the forty-eighth part of an inch in diameter.

Near the bay of Acra, in Palestine, runs a little river, now called Kardanah, supposed to be the ancient Belus, famous for its sand, much used in making glass, and said to have given rise to the invention of it. The Sidonians are reported to have made this discovery, from the following accident. Some travellers having reared an hearth on the sand of this river with large pieces of nitre, and set some fern on fire under a kettle, in order to boil their victuals, perceived the sand and the nitre to melt and incorporate with the fern-ashes, and presently after to run in a transparent stream, which hardened as it cooled. From hence the hint of making glass was taken, which was gradually improved to its perfect use and beauty.

28. There are few phænomena relative to glass more hard to be accounted for, than that of the Bologna bottle, so called, because it was first discovered at Bologna. If you let these bottles fall from some height on a brick-floor, they will not be broken; but drop into them some hard body, and they will burst in pieces. I took one of these, says Dr. I. which held near a pint, and let it fall five feet and a half on a brick floor, and it was not broken. I dropt into it a bit of flint, weighing

weighing eleven grains, and immediately it burst in pieces.

I dropt into another bottle a ball of lead, weighing one hundred and forty grains, into a third a piece of brass weighing three hundred grains, and neither of them was broken.

These glasses only differ from common phials in this, they have not cooled gradually in what is called, the nealing furnace, but are exposed to the open air as soon as formed. They resist hard blows from without. I have given to some, violent strokes with a mallet, and they have not broke. They likewise do not break, though several heavy bodies be dropt into them. I have dropped into them from the height of three feet, musket-balls, and pieces of iron, brass, gold, without any effect; but when I dropt into it from the height of three inches, a shiver of flint no bigger than a small pea, in about two seconds the glass flew. Having tried the experiment on several others with the same piece of flint, most of them broke in the moment of the stroke, the rest one or two seconds after it.

I let fall into several glasses a flint of half the size, and they flew in like manner. I let fall into one, a flint no larger than a grain of sand, shook the glass, and set it down. I did the same with four others. In about half an hour one of them flew, and the other four soon after.

I let fall into one a sapphire set in a ring: and though the bottom of the glass was near an inch thick, the sapphire passed through it as through a spider's web. The glass flew all ways, and the ring remained on the table, just where it fell.

A bit of china, half a line thick and two lines broad, broke several glasses, so did a bit of glass of the same size; so did diamonds also. And a
very

very small piece of tempered steel, broke all the glasses into which I dropped it.

Some large hollow cups made at Worcester of common green glass, much larger than the others, and some of them above three inches thick at the bottom, though they were not affected by a musket-ball, dropt from the height of near three feet, were instantly broken with a shiver of flint, weighing but two grains.

There is something astonishing in the power of Telescopes, to bring far distant objects near; and of Microscopes, to render those clear and distinct, which are quite invisible to the naked eye. And no less amazing in another kind, is the force of burning glasses. 1. A piece of wood laid before a large burning-glass, took fire in an instant. 2. Water contained in an earthen vessel boiled immediately, and in a short time quite evaporated. 3. A mass of lead, three inches thick, began to melt in a moment, and soon after ran in a continued thread. 4. A steel-plate grew red-hot almost in an instant, and small holes were made through it. 5. Slate becomes black glass, tiles, yellow glass, earthen pots, a darkish yellow glass. 6. A pumice stone became white glass, earth black glass, bones an opaque one.

But in the extremely hot weather at Paris in 1705, the rays of the sun, collected by a large glass, had scarce any force, though the separate rays quite inflamed the air. The reason of so surprising a thing seems to be, that the heat raised from the earth's great sulphureous exhalations, which embarrassed, stopped, and in some degree absorbed the rays of the sun.

29. Equally strange are the phenomena of the Glass-drop. The make of this drop is as simple, as
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its explanation is difficult. They take up a small quantity of melted glass on the top of an iron rod, and let it drop into a pail of water. When it does not break in the operation, it forms the Glass-drop. This is of such firmness, that it bears smart blows of a hammer, without breaking. But if you break only the tip of the small end, the whole shatters into powder. This shattering is attended with a loud report, and the powder scatters all around. If the experiment be made in the air-pump, the drop bursts more impetuously, and the dust is finer than when it bursts in the open air. This is a plain matter of fact. I do not undertake to account for it.

Gunpowder is commonly supposed to have been invented by Barthold Schwartz, about the year 1380. But Roger Bacon knew of it, an hundred and fifty years before Schwartz was born. For in his treatise de Nullitate Magica, published at Oxford in 1216, are these words. " You may raise thunder and lightning at pleasure, by only taking sulphur, nitre, and charcoal, which single have no effect, but mixed together and confined in a close place, cause a noise and explosion greater than that of a clap of thunder."

The effect of gunpowder is owing to the spring of the air, inclosed in the grains and in the spaces between them. All these springs are dilated by the fire, and set a playing at once. The powder itself only serves to light the fire, which puts the air in action.

Aurum fulminans, a preparation of gold, is far stronger than gunpowder. A scruple of this acts more forcibly than half a pound of that. A single grain laid on a knife, and lighted at a candle, goes off with a greater noise than a musket.

30. Air

30. Air is that clear, transparent, compressible fluid which is extended about a degree round the terraqueous globe, being with us about 46,656,000,000 times more dense and sluggish than æther, betwixt which and the air there is a very great affinity or attractive force, which is as their density; i. e. the air contiguous to the æther takes in and concentrates the æther proportionally to its greater density, by which it is rendered more springy and active, with this difference, that the air by contact and cohesion in the parts of bodies, becomes solid and unelastic (but æther never); from whence again, by heat, fire, or dissolution of parts being separated, its elasticity returns. This element has a near affinity or relation to water, because it eagerly takes up rarified water into itself, as water again drinks up a portion of air within its contact; so that air and water actuated by æther, make the levers and wedges by which nature performs all her changes in bodies. And it serves as the common medium of communication between us and all bodies.

The pressure of a column of air upon a square inch only, is equal to fifteen pounds weight. That upon the surface of an human body, generally amounts to at least thirteen ton weight: seeing all fluids press with an equal force every way, upwards, downwards, sideways, and in all directions. If then every square inch on a man's body, sustains a pressure of 15 pounds, the pressure on the whole surface of a middle-sized man, will amount at least to 13,320 pounds.

"But how is it then that our bodies are not crushed in pieces?" Our bodies, as well as all others, are filled with air throughout: and the spring of the internal air is equal to the pressure of

of that without. And when two equal forces act in contrary directions, they entirely destroy each other's effects: hence however, if the ambient air presses upon us, it is all one as if did not press at all.

The elasticity of the air is a counterbalance to its gravitation. And how necessary is it, that these should balance each other? Were the power of gravity to be suspended for a moment, and that of elasticity to remain, the atmosphere would instantly be dissipated, through the infinite regions of space. But while the weight of the air and its elastic force are equal, they produce an equilibrium among the particles of air, in every part of the atmosphere.

As the higher it is, the air is more and more expanded, gravitation being less and less, so the parts of the air in the upper regions will be expanded only not to infinity.

The air is generally invisible. And it is necessary it should be so. For as it is the medium through which we see objects, if the parts of it were perceptible, it would render the view of those objects far less perfect and distinct. Hence a greatly magnifying telescope, as it shews the body of air, makes the view of other objects more confused.

Yet in some cases you may seem to see the air. In a very hot summer's day, in an open part of the country, place yourself on an eminence, nearly facing the sun. Then, if there be a gentle wind, there will be a reflexion of light from the body of the air in the vale below. And you will see the undulations or waves of air almost as perfectly as you may those of water, agitated by a gentle wind. And yet in truth, it is not the air which you see, but the vapours that float therein.

One property of air is its Weight or Gravity. This you will immediately feel, if you lay your hand on the mouth of a vessel, which is emptied of air. If you lay a square piece of glass on the orifice of an Air-pump, when the air is drawn out, it will be broke to shivers with a great noise. Or extract the air from between two smoothly polished marbles, and close the edges with wax, they will then be so strongly prest together, as not easily to be separated. But we need no other proof of it than the Barometer: a glass tube, close at one end, and filled with mercury. Immerse the other end in a basin of the same fluid, and when it is erected, the mercury in the tube will rise thirty inches, above the surface of that in the basin.

The changes then in the Barometer are wholly owing to the changes in the weight of the atmosphere. But to what are these owing? It seems, chiefly to the winds, For 1. These must alter the weight of the air in any particular place, either by bringing together and accumulating the air, which is the case when two winds blow at the same time from opposite points; or by sweeping away part of the air, as when two winds blow opposite ways from the same point; or lastly, by cutting off the pressure of the atmosphere, which happens when any wind blows briskly any way: 2. Cold, nitrous particles load the atmosphere, and increase its weight: 3. So do heavy, dry exhalations from the earth, 4. The air being rendered heavier is more able to support the vapours, which being intermixed with it, make the weather fair and serene. When it is rendered lighter by the contrary causes, it becomes unable to support the vapours, which then sink, gather into drops, and fall in rain.

With us the mercury is highest when the wind is north or north-east, and so brings the cold, condensed air of the northern climates. In all northern countries the mercury varies more than in the southern, the winds being more frequent, strong, various and opposite to each other. Between the tropics it scarce varies at all, the winds being small, and generally blowing the same way.

The pressure of the air, is, *cæteris paribus*, as its height. Carry the Barometer to an higher place, where the incumbent column of air is shorter, and a shorter column of air is sustained: it being found to descend at the rate of a quarter of an inch for every hundred feet of ascent.

Now air, as all other fluids, must press equally every way. Hence it is, that soft bodies sustain their pressure, without any change of figure, and brittle bodies without breaking, though that pressure be equal to that of a column of mercury, thirty inches high, or a column of water of thirty feet. Nothing can keep these bodies unchanged, but the equable pressure on all sides, which resists as much as it is resisted. And hence on removing or lessening that pressure on one side, the effect of it is soon perceived on the other.

It is by means of its gravity, 1. That the air closely invests the earth with all the bodies on it, and bends them down: that it prevents the arterial vessels of plants and animals from being too much distended, by the impetus of the circulating juices: and that it hinders the blood from oozing out, through the pores of their containing vessels. Hence they who travel up high mountains, the higher they ascend, are relaxed the more, till they fall into spitting of blood.

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2. The mixture of contiguous fluids is chiefly owing to this. Hence many fluids which readily mix in the air, when that is removed, remain separate. 3. It determines the action of one body upon another. Thus it presses the particles of fire against the fuel. Whereas upon removing the air, the fire immediately goes out. So Aqua Regia ceases to dissolve gold, if the air be taken away: hence also on the tops of high mountains, as on the Pike of Teneriffe, the most acrid bodies, such as pepper, ginger, salt, have no sensible taste; for want of a sufficient gravity in the air to press their particles into the pores of the tongue.

Another property of air is Elasticity. It yields to an impression, by contracting its dimensions, and returns to them, on removing the impressivè cause. This endeavour to expand itself, every particle of air continually exerts, against an equal endeavour of the ambient particles. Hence it is, that a bladder full of air, will burst in an exhausted receiver: while one that before seemed empty, swells and appears to be full of air.

This power does not seem to have any bounds. Nor is it easy to be destroyed. Let air be expanded ever so much, it still retains its spring. Nor is this sensibly diminished by any experiment which has yet been made.

There is no fixing any bounds to its condensation, any more than to its dilatation. It will dilate into a thousand times its former space, yea into 13,679 times. And all this by its own expansive force, without any force of fire. The air we breathe near the surface of the earth is compressed by its own weight, into at least the

13679th part of the space it would possess in vacuo. And if the same air be farther condensed by art, the space it will take up when most dilated, will be (according to Mr. Boyle) to that it possessed when most condensed, as 550,000 to one.

If while we increase the elasticity of air, on one side by compression, we increase it on the other side by heat, the force of both soon becomes irresistible; and a French philosopher supposed, that air thus confined and expanding was sufficient for the explosion of a world. In order to determine the Elasticity of air, the wind-gun has been invented, which is an instrument that compresses a large quantity of air into a tube in which there is an ivory ball, and then gives the compressed elastic air free power to act and drive the ball as directed. The ball thus driven will pierce a thick board, and will be as fatal at small distances, as if driven with gun-powder. I do not know whether ever the force of this instrument has been assisted by heat; certain I am, that this, which could be very easily contrived by means of phosphorus, or any other hot substance applied to the barrel, would give such a force as I doubt whether gun-powder itself could produce.

Every thing we see gives of its parts to the air, and has a little floating atmosphere of its own round it. The rose is encompassed with a sphere of its own odorous particles; while the nightshade infects the air with scents of a more ungrateful nature. The perfume of musk flies off in such abundance, that the quantity remaining becomes sensibly lighter. A thousand substances that escape all our senses, we know to be there; the

the powerful emanations of the loadstone, the effluvia of electricity, the rays of light, and the insinuations of fire. Such are the various substances through which we move, and which we are constantly taking in at every pore, and returning again with an imperceptible discharge.

The great mixture of all earthly bodies is continually operating upon itself; which perhaps, may be the cause of its unceasing motion; but it operates still more visibly upon grosser substances, as are exposed to its influence; for scarce any substance is found capable of resisting the coroding qualities of the air. The air, say the chymists, is a chaos furnished with all kinds of salts and menstrooms; and therefore it is capable of dissolving all kinds of bodies. It is well known that copper and iron are quickly eaten with rust; and that in the climates near the equator no art can keep them clean. In those countries, instruments, knives, and keys, though kept in the pocket, nevertheless are quickly incrustated; and the great guns, with every precaution, after some years, become useless. Stones may be supposed to be more easily soluble. The marble of which the noble monuments of *Italian* antiquity are composed, although in one of the finest climates in the world, nevertheless shew the impressions which have been made upon them by the air. In many places they seem worm-eaten by time; and in others they appear crumbling into dust. Gold alone seems to be exempted from this general dissolution. It is never found to contract rust, tho' exposed never so long: the reason is, that sea-salt, which is the only menstruum of gold, is but very little mixed with the air, being a very fixed body, and not apt to volatilize. In the elab-

boratories however, where the air is impregnated with it, gold is found to rust, as well as other metals.

By its elasticity air insinuates into the pores of bodies, carrying with it this faculty of expansion; whence it must necessarily put all the particles it is mixed with, into perpetual oscillations. And as its elasticity is never the same for two moments together, there must be an incessant dilatation and contraction in all bodies. To this is owing all putrefaction and fermentation, neither of which will proceed in vacuo. And indeed all natural corruption and alteration seem to depend hereon: so that metals, particularly gold, are so durable, only by being impervious to air. And yet it may be doubted, whether air itself be the true, original, universal dissolvent; or rather the ethereal fire, which is intimately united with every particle of it: and without which air is effete and useless, neither able to feed flame, nor to sustain animal life.

That there is some matter in the air much finer than the air itself, appears from many considerations. In an exhausted receiver something remains, which conveys the heat, near as readily as air. Now this must be a body, and a body subtle enough to penetrate the pores of glass. Doubtless then it penetrates the pores of all other bodies, and consequently is diffused thro the universe. And this seems to be not only more subtle than the air, but far more weighty and elastic. To the weight of this may be owing the weight of the air, and of all other bodies: to its elasticity, the elasticity of the air, and of all other elastic bodies. This also may cause the reflection and other phenomena of light: as also sensation, and muscular motion. Indeed it seems to be the first spring of all the action in the universe.

Air is sometimes deprived of its elasticity, and wrought

wrought into the substance of other bodies, from which nevertheless it may be extracted, and resume its elastic state. As to *animal substances*, a very considerable quantity of air is extracted from them by distillation, not only from the blood and fat, but also from the most solid parts of animals. Half a cubic inch of a fallow deer's horn, produced 117 cubic inches of air: half a cubic inch of Oyster shells, no less than 162 cubic inches.

As to *vegetable substances*, half a cubic inch of Heart of Oak generated 108 cubic inches; a cubic inch of Peas 396 cubic inches, or 113 grains, which was above a third of its weight. This air will flash, if touched with a candle.

Camphire generates no air: Brandy next to none: well water, or Rain-water, a little: Pyrmont-water, twice as much: which air contributes to the briskness of this and other mineral waters.

From Minerals much air may be extracted. Half an inch of Newcastle Coal yielded 180 inches of air, which weighed near one third of the coal.

Yet a good part of the air extracted from these bodies, in some days gradually lost its elasticity: because the acid, sulphureous fumes, raised with that air, resorbed and fixed the elastic particles. But when a means was found, to prevent this, it lost only a seventeenth or eighteenth part: and that chiefly in the first twenty four hours; the rest was permanently elastic.

There is another way of producing air, which seems to be more natural, namely by fermentation. A cubic inch of * Oil of Vitriol with half

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* Mr. Geoffry shews, that the mixture of any vitriolic salts with inflammable substances, will yield common Brimstone: particularly of oil of Vitriol with oil of Turpentine. Brimstone therefore is nothing but vitriolic salt, united with some combustible substance.

an inch of Sal Ammoniac generated six cubic inches of air: six inches of powdered Oyfter-shells, and an equal quantity of White-wine vinegar, generated twenty-nine inches.

That much air is incorporated into the substance of *vegetables*, appears from the following experiments.

Forty-two inches of Ale from the tun generated in three months, 636 cubic inches of air: twelve inches of Malaga-raifins, in six weeks generated 411 inches: twenty six inches of Apples, in thirteen days generated 968 inches of air. They then in three or four days reſorbed about twelve inches, and afterwards neither generated nor reſorbed.

That the air ariſing from diſtilled or fermenting bodies, is true air, appears from hence, that it continues in the ſame expanded ſtate for weeks, or months, which expanded vapours will not do. And that it is elastic appears, by its dilating and contracting with heat and cold, as common Air does.

Air then makes a very conſiderable part of the ſubſtance of vegetables as well as animals. And beſide theſe particles of air, which ſtrongly adhere to, and are wrought into their ſubſtance, there is in them a large quantity which is upon the wing, and in a very active ſtate.

To ſhew how much air is contained in white paper, take as many ſlips of it as weigh an hundred grains. Burn theſe warily by the flame of a candle, and then weigh the aſhes. You will find the hundred grains reduced to ſix. So ninety four grains out of one hundred, are undeniably *transformed* into Air. They could not be annihilated. And they could not riſe and fly away without a repelling force to carry them off. Thus
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the candle itself is by degrees transformed from heavy, palpable wax, into a light, impalpable body of air. But observe: all bodies which thus become Air, pass through the intermediate state of Flame. So that, properly speaking, the same body was one moment *paper*, the second moment *fire*, and the third, *Air*. How different states for the same sort of matter to subsist in, in so short a time.

The Air-pump shews how much Air is, even in water. Place a tall glass of water in the receiver. Turn the winch, and you see bubbles of Air through the body of the water. First, they are thick, but small; then they grow large, and rise to the top of the water. And as long as the pump works, so long the Air rises, but more slowly, and in larger bubbles. In wine the Air-bubbles rush violently to the top and burst. Nay, and the liquor perfectly boils, like water on the fire. Yea, and hot water may be made to boil by the Air-pump, as well as by fire. Hence it appears, that boiling is nothing but the motion produced from the expansion of the Air, whether by fire, or by the warmth and pump conjointly.

By another experiment it appears, that any piece of wood is pervious to the Air, and that its Air-vessels run through the whole length or substance of the tree. Nay, quicksilver may be made to pass through a piece of wood, and descend in the form of a shower of rain.

By the Air-pump we likewise measure the weight, and find that a pint of it weighs 8 grains. Consequently a gallon weighs a little more than a drachm: therefore a bushel weighs an ounce and half a drachm.

Another experiment proves what one would not suspect. Bodies moving in a fluid, meet so

much the more resistance, as their bulk is larger in equal weight. So a cork of equal weight with a guinea, meets with so much the more resistance from the Air. But in an exhausted receiver, the largest bulk of cork, which was before the most resisted, now proves the heavier body, and accordingly falls *more swiftly* than the gold.

Again. Strike a flint against the steel *in vacuo*, and it will occasion no sparks. So necessary is Air to the very appearance of fire.

Air is generated likewise from minerals by fermentation. By other fermenting mixtures it is absorbed again, and by others generated and absorbed alternately.

A quarter of an inch of *filings of iron*, and an inch of compound *aqua fortis*, in four days absorbed 27 inches of Air. When hot water was poured upon it, it generated three or four inches, which after some days it absorbed again. A quarter of an inch of Iron filings, with an inch of powdered Brimstone, absorbed nineteen inches in two days. Powdered Brimstone mixed with Newcastle Coal, neither generated nor absorbed.

An inch of Chalk, and as much Oil of Vitriol in three days generated 31 inches of Air. Part of this it afterwards reformed. Two inches of Lime and as much Sal Ammoniac absorbed 115 inches. The fumes of this are therefore very suffocating. All burning and flaming bodies, absorb much air. And whereas the air which some substances absorb, is afterwards remitted, that which is absorbed by burning brimstone, by the flame of a candle, or by human respiration, does not recover its elasticity.

The elasticity of the Air in the vesicles of the lungs is continually decreasing, through the vapour it is there loaded with: so that there needs
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fresh air continually; otherwise those vesicles will soon fall flat, whereby the motion of the blood through the lungs being stopt, instant death ensues. And this seems to be exactly the case of most of those, who are killed by lightning, which so totally destroys the elastic Air in the lungs, that they instantly fall flat.

31. Many have imagined that the animal fluids are furnished with Air by the lungs only. But undoubtedly they are also supplied therewith, by way of the chyloferous canals: and that in no small quantity. For the Air, like all other animal fluids, requires to be perpetually renewed; accordingly old particles fly off every moment, and new ones succeed in their place.

It may be demonstrated, that urine contains much air. Doubtless so does the perspirable matter: which being the lightest of all animal fluids, is the chief vehicle of the effete and useless Air.

And that candles soon go out, if they are confined in a small quantity of Air, seems not to be so much owing, to their having rendered the Air effete, by consuming its vivifying spirit, as to its destroying the elasticity thereof, by its acid, fuliginous vapours.

But nothing destroys the elasticity of air like brimstone, whether burning or in fermenting mixtures. And as the attractive power of bodies, is found to be more or less, as they have more or fewer sulphureous particles, so we may reasonably ascribe the fixing the elastic particles of Air, to the strong attraction of the sulphureous particles, with which Sir Isaac Newton supposes all bodies to abound, more or less.

The various mixtures in the stomach, sometimes

generate, sometimes absorb Air. In a good digestion the generating power exceeds the absorbing power but a little. When it exceeds it much, we are troubled more or less, with distending flatus's.

We have seen how much Air may be extracted from animal and vegetable bodies, into whose substances it was before intimately and firmly incorporated. And consequently great quantities of Air must be continually expended in their production. Part of this, we see, may resume its elastic state, when their texture is dissolved: but part probably never regains its elasticity, at least, not in many centuries. However, we may see, what immense treasures of this important element, the wise Author of nature has abundantly provided, the constant waste of it being abundantly supplied, by heat or fermentation from innumerable dense bodies.

If all the parts of nature were endued with a strongly attracting power only, whole nature would immediately become one unactive, cohering lump. It was therefore absolutely necessary there should be every where intermixed, a due proportion of strongly elastic particles. And since abundance of these are continually reduced from an elastic to a fixed state, it was also necessary that these particles should be endued with a property of resuming their elasticity, whenever they were disengaged from that mass, in which they were fixed. And hereby this beautiful frame of things, is maintained in a continual round, of the production and dissolution of animal and vegetable bodies.

The Air is very instrumental in the production and growth of animals and vegetables: in its elastic state, by invigorating their juices; and in its

its fixed state, by greatly contributing to the union and firm connection of their constituent parts. It is also a very powerful agent in the dissolution of the same bodies.

32. That fixed air is a cementing principle, appears (to omit others) from that well known experiment. Quick lime dissolves flesh, by extracting and imbibing the fixed air, which it contained. But while the flesh falls in pieces from the loss of the principle, the lime grows solid by having it restored.

That it contributes also to the *dissolution* of bodies appears hence. During the progress of Putrefaction, a volatile matter flies continually from the putrifying substance. And this is no other than air, which is now extricated and thrown off from a fixed and unelastic state, but immediately returns to it again, on meeting with a proper recipient.

The preserving bodies from Putrefaction, depends almost in every instance, on restraining the flight of the fixed air. For as this cements their constituent parts, so Putrefaction, which is the dissolution of them, cannot take place while this remains.

And this Air both corrects, and prevents putrid acrimony in the animal fluid. Hence any food which does not contain a due proportion of it, is found to promote putrefaction: as do all damaged vegetables, which being incapable of fermentation, are incapable of producing the due quantity of air.

But pure air is no where to be found. That which surrounds us is the most heterogeneous body.

body in nature. It is no other than an universal chaos, a colluvies of all kinds of bodies. No bodies can withstand the force of fire. And whatever fire can volatilize is found in the air. Hence for instance, the whole fossil kingdom must be found therein: for all that tribe is convertible into fume. Gold, the most fixed of all adheres to sulphur in mines, and is raised along with it. All the parts of the Animal kingdom must likewise be in the air. For besides the copious effluvia they emit by perspiration (whereby an animal in the course of its duration, impregnates the air with many times the quantity of its own body) any dead animal, when exposed to the air, is in a certain time carried wholly off. And we know that all vegetables by putrifaction become volatile, and so evaporate into air.

Air, 2. volatilizes fixed bodies. Thus sea-salt being calcined and fused, then exposed to the air to liquify; when liquified, set to dry again; then fused again, and the operation thus repeated; will by degrees be almost wholly evaporated, nothing remaining but a little earth.

Air, 3. fixes volatile bodies. Thus though aqua fortis or spirit of nitre, readily evaporates by the fire; yet if the air near be impregnated with spirit of urine, the volatile spirit is fixed, and falls down in a liquid form.

But the air's being open or inclosed is of consequence in chymical operations. So, to make sulphur inflammable, a free air is required: in a close vessel it will not kindle. And thus all animals and vegetables can only be calcined in open air. In close vessels they never become any other than black coals.

By the Air-pump the air is in a great measure drawn out of a vessel called the Receiver. And hence we learn how much all vital, nutritive and alterative powers depend upon the air. A candle in the exhausted receiver usually goes out in a minute. A kindled charcoal is totally extinguished in about five minutes. Red hot iron is not affected thereby: only it will not light sulphur or gun-powder, but melt it. Load-stones act, as well as in the open air. Smoke sinks in a darkish body to the bottom, leaving the upper-part, clear and transparent. The syphon does not run therein: but attrition produces heat, as in the open air. If some grains of an heap of gun-powder be kindled by a burning-glass, they will not fire the contiguous grains. Glow-worms lose their light as the air is exhausted; but recover it not on its readmission. Vipers and frogs seem dead in less than two hours, but recover in the open air. Snails live ten hours: efts two or three days; leeches five or six.

The atmosphere is a body of air and vapours, which surrounds the globe to the height of about sixty miles, gravitates towards its center, and is carried along with it in all its motions. This continually presses on our bodies, with a weight equal to a pillar of air, whose base is equal to the surface of our bodies. Now a pillar of air of the height of the atmosphere, is equal to a pillar of water thirty-two feet high. Every foot square therefore of the surface of our bodies is pressed on by a weight of air, equal to 35 cubic feet of water: and a cubic foot of water weighing 76 pound (Troy weight) consequently every foot square of the surface of our bodies sustain a pillar of air, equal to 2,260 pounds. If then the surface of a man's body contains fifteen square feet, he sustains

sustains a weight equal to 39900 pounds. This is the case, when the air is heaviest. But the difference between the greatest and the least pressure of air upon our bodies is equal to 3982 pounds.

Hence it is so far from being a wonder, we should sometimes suffer in our health, by a change of weather, that it is the greatest wonder we should not always suffer. For when we consider our bodies are at some times prest upon by near two ton weight more than at others, it is surprising that every change does not break our whole frame to pieces.

In truth the vessels of our bodies being so much straitened by an increased pressure, would stagnate the blood to the very heart, had not the author of nature wisely contrived, that when the resistance to its circulation is greatest, the force by which the heart contracts should be so too. For upon an increase of the weight of the air, the lungs are more strongly expanded, and the blood by being more intimately broken, made fitter for finer secretions, the nervous in particular, by which the heart is more strongly contracted. On the other hand, when the weight of the ambient air is ever so little abated, the air contained within the blood, unfolds its springs, and forces the blood to take up a larger space than it did before.

The reason we are not sensible of this pressure, is well explained by Borelli: sand perfectly rammed into an hard vessel, cannot be penetrated, even by a wedge. And water in a bladder compressed on all sides, cannot give way in any part. In like manner, within the skin of an animal, are contained various parts: some hard, as bones; some soft, as muscles; and some fluid, as blood. Now it is not possible that bones should be broke

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or displaced in the body, unless the pressure lay heavier on one part than another. If the pressure be so divided, that it be equal all round, upward, downward, sideways, and no part of the skin to be exempt therefrom, it is plain, no fracture or luxation can follow.

The same may be observed of the muscles and nerves, which though soft, yet being composed of solid fibres, do mutually sustain each other, and resist the common weight. The same holds of the blood and other humours. As water is not capable of condensation, so these liquids, while contained in their vessels, cannot be forced out of them by an universal compression. Add to this, that the air itself which is contained in every part of the body, is such a balance to the external air, that no hurt can ensue from its pressure.

33. Oil of vitriol, when exposed to the Air, continually increases in weight. Let a phial of this stand unstopped, and it will be constantly running over. Perhaps the cause of this odd phenomenon is, the moisture contained in the air, which this liquor, a potential fire, imbibes as greedily, as actual fire does nitre.

34. At the height of forty-one miles, the air is so rarified, as to take up three thousand times the space it does here. At fifty-three miles high, it would be expanded thirty thousand times as much as it is here. But it is probable, the utmost power of its spring, cannot produce so great an expansion: and that no part of the atmosphere extends above forty-five miles from the surface of the earth.

At that distance, (as was observed) it is expanded

ed into three thousand times the space it occupies here. And we have seen it condensed into the sixteenth part of the same space. It seems then, that the Air is capable of being condensed into the hundred and eighty thousandth part of the space it would take up when free from pressure. But what texture must it be of, to make it capable of this immense expansion and contraction? How imperfectly is this accounted for, by comparing it to wool, cotton, and the like elastic bodies.

35. But there is an amazing difference between the fixed, and the common Air, with regard to their effects upon animal bodies. The fixed Air, even when set free, and in a state of perfect elasticity, whether it be during the first stage of fermentation by fire, by effervescence, or by putrefaction; if it be received into the lungs of any animal, causes instant death. But the same air, when received into the stomach, whether thrown off by effervescent mixtures in medicine, or extricated from the food by natural fermentation; in the first instance often operates like a charm, in restraining vomitings; and in the second is absolutely needful, for the support of life and health.

With regard to the common Air, on the contrary no animal can live long without taking large quantities of it into the lungs. Yet if a small portion of it be forced into the blood-vessels of any animal, death presently ensues.

So that these two species of air have quite different provinces, with respect to animal life. The first, common Air must mix wholly with the blood. The second only communicates some subtle matter to it: probably electric fire, which we know is connected with every particle of common air.



C H A P. III.

O F M E T E O R S.

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| 1. <i>Of Vapours, Mists,
and Clouds.</i> | 7. <i>Of Thunder and
Lightening.</i> |
| 2. <i>Of Dew and Rain.</i> | 8. <i>Of Damps.</i> |
| 3. <i>Of Snow and Hail.</i> | 9. <i>Of Ignis Fatui.</i> |
| 4. <i>Of the Rainbow.</i> | 10. <i>Of Electricity.</i> |
| 5. <i>Of the Haloe</i> | 11. <i>Of Ether of Plants.</i> |
| 6. <i>Of mock Suns and
Moons.</i> | 12. <i>Of Wind.</i> |
| | 13. <i>Reflections.</i> |

1. **W**HATSOEVER is carried aloft into the air, and suspended there, is termed a Meteor. These are either Watry, Fiery, or Airy. The Watry, are Mists, Clouds, Rain, Snow, Hail. Watry particles which are rarefied so as to float in the air, are then termed Vapours. If these are visible and hang near the earth, we call them Mists; if they are higher in the air, Clouds. Some of these are so thin, as to transmit the rays of the sun, others so dense as to intercept them.

The manner wherein the vapours that constitute clouds and rain are raised, seems to be this. Fire being the lightest of all bodies, easily breaks loose from them; and in its passage carries along with it particles or little cases of water. These being lighter than the air, are buoyed up and swim therein: till striking against one another, or thickened

thickened by cold, they are reduced into clouds and drops.

To illustrate this, we may observe in water over the fire, 1. That the evaporations are proportioned to the heat. As small heat throws off few vapours, scarce visible: a greater heat carries off larger and more numerous vesicles of water, which we call a Steam. Violent heats lifts up great quantities of water, which the air cannot buoy up: and this we call Boiling. 2. If these vapours be intercepted in their ascent, by any dense body, especially if it be cold; they are thereby reduced into drops, like those of rain. 3. In frosty weather the vapours rise but a little above the water, and there hang or glide on. If the weather be cold; after a little ascent, they fall again into the water. But in a warm still air, they ascend swiftly and largely, and mount up, till they are out of sight.

To explain this a little farther, it may be observed, that the parts of water being so small and moveable, are easily separated from one another. And when they are so divided into small parcels, as to become about eight hundred times lighter than common water, they are as light as the air, and will by every successive degree of separation, rise in the air in proportion to their lightness, the heavier air forcing the rarified fluid to ascend into the atmosphere, till it finds a place in equilibrium among bodies of equal lightness to itself. This separation or comminution (if I may so call it) of water into small parcels, may be performed either by collision against harder and more compact bodies, or by heat. The first we often see performed at the bottom of cascades, where the water that falls but a few fathoms, shall rise in a mist from the bottom where it is broke; and there are

are instances of clouds rising from the fall of waters, which may be seen five miles off. Collision will therefore excite vapours; but what is more constantly producing this effect in every part of the universe, is heat; whether from the sun, which is always busy this way, or from artificial ignition, or that generally invisible elemental fire, which is distributed through all matter. It is not necessary for us to consider in this case, any other than the divisibility of water, and the insinuating and dispersive qualities of fire. Fire we see separates more or less the parts of all bodies, whether fluid or solid, and makes them rise in the air; and it does no more to water: it separates it into such small portions, that the air is more ponderous than the steam, and of consequence remains nearer the earth by its superior gravitation.

2. The Dew which usually falls in England in a year amounts to something more than three inches and a quarter depth. The evaporation of a winter's day is nearly the same as that of a summer's day. For the earth being moister in winter, that excess of moisture answers to the excess of heat in summer.

Within the tropics they have no rain for many months together. But the Dews are far greater than with us. Yet the moisture evaporated in a summer's day, far exceeds that which falls in the night. Hence the dews there, cannot be of any benefit to the roots of the trees, because they are remanded back from the earth by the following day's heat, before they can soak to any considerable depth. The great benefit therefore of Dew in hot weather must be, by being imbibed into vegetables, to refresh them for the present, and supply them with moisture towards the expence of the succeeding day.

Mean

Mean time the sun draws fresh supplies of moisture from the strata of the earth, which by means of its penetrating warmth insinuates itself into the roots. By the same genial heat it is carried up through their bodies and branches, and thence passing into the leaves, it is vigourously acted upon in those thin plates, till perspiring through their surface, it mounts with rapidity in the free air.

But the strangest circumstance relating to Dew, is this. In the same night place several substances in the open air, whilst a large Dew falls; and some of them will receive much of it, some little, and others none at all. The drops make a sort of choice, what bodies they shall fix themselves to. Glass and chrystals they fix themselves to readily, and in the largest quantities. Metals do not receive them at all, nor do the drops ever fix on them. If a glass vessel be set out in the evening, on silver plate, the glass will be found quite covered with Dew, and the silver perfectly dry. China-ware is a sort of glass. Six pounds of mercury being exposed to the air in a china plate, the Dew ran in streams on the edge of the plate, but not a drop was on the mercury.

Is there not some alliance between the phenomena observed in Dew, and those which appear in electric bodies? All hard bodies may by rubbing become electric, excepting only metals. And metals are the only bodies which wholly refuse to admit the Dew.

But this is not all. A pewter plate placed all night in the open air, receives no Dew on its upper-side, but the under-side is covered with it. On the contrary, place a china plate near it, and the upper-side of it is quite wet, but the under-side is quite dry. So one receives the Dew only
on

on the upper, the other only on the under surface! Who can account for this?

Mr. Kershaw has observed, that Dew newly gathered and strained, is not very clear, but of a yellowish colour:

That when he endeavoured to putrify it by various degrees of heat, he quite failed of his intention: for heat rather clarified and preserved it sweet, than caused any putrifaction:

That after it had been exposed to the sun, corked up, for a whole summer, there was no other change than that much green stuff (such as we see in standing water) floated on the top:

That after it had been exposed to the sun many weeks in an open glass, it was full of little insects, like tadpoles, which in a while dropt their skins, and became gnats:

That vapouring away great quantities of this dew, he procured two pounds of greyish earth, which lay in leaves, one above another, like brown paper, but very friable:

Lastly, that by often calcining and filtering this earth, he extracted two ounces of a fine, small, white Salt, which much resembled Rock Salt, it was when viewed through a microscope.

If clouds are condensed, so as to fall in drops, this we stile Rain. It may rise from various causes. Sometimes cold alone condenses a warm cloud. But it is generally wind which presses the cloud so close together, that the particles of water unite in large drops, which being specifically heavier than the air, can no longer be suspended by it.

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But by what power are the Drops of Rain so equally dispersed? This may be shewn by an easy experiment. Put a quantity of brass-dust into an electric phial. When this is charged, invert it, and throw some of the dust out. This will be spread over a flat surface, with exact uniformity, and will fall just like Rain or Snow. It is highly probable, this is the case with the clouds. Being highly electrified, they of course spread their contents equally over the surface of the earth.

Again. How comes it to pass, that we have not constantly either too much or too little rain in any one place? It is not chance, which can never steer clear of extremes. It is the hand of Providence. There is no other rational way of accounting for such an œconomy in the clouds. Such a just and necessary distillation and distribution of water from the grand alembic of the atmosphere, could never proceed, but from the superintendence and direction of that Omnipotent Chymist, in whose hands are all the secondary powers of nature, to vary their operations, as he sees most conducive to the general good of mankind.

Bloody Rains, as they have been sometimes called, seem to be only the excrements of insects. Accordingly Gassendus gives us an account of a bloody rain in France which much terrified the people. But upon enquiry, it was found only to be red drops, coming from a sort of butterflies which flew about in great numbers.

During a scarcity in Silesia, a rumour was spread, of its raining Millet-Seed. But it was soon

soon found to be only the seeds of the small Hen-bit, growing thereabouts in great plenty. So in the Archipelago it was thought Ashes were rained, with which ships were covered for many leagues. But in truth, they came from an eruption of Vesuvius happening at that time. More lately, it was reported at Warminster in Wiltshire, that it rained Wheat. But the supposed Wheat was really Ivy-berries, blown thither in a considerable quantity by a hurricane. Nay, in 1696 a field near Cranstead in Kent, was overspread with young whittings, supposed to fall from the clouds, but doubtless brought thither from the sea, by a violent storm.

Nor is it strange that any of these things should be thus transported by tempestuous winds, considering to what distance, and in what quantities the sea-water was carried by the storm, Nov. 26, 1703. A physician travelling soon after, twenty miles from the sea, chewing some tops of hedges, found them salt. The grass of the down about Lewes was so salt, that for some time the sheep could not eat it. And the Miller, three miles from the sea, attempting with his man to secure his mill, were so washed with flashes of sea-water, that they were almost strangled.

A few years ago, during a violent storm of wind, much rain fell in the western part of Cornwall, which was mere sea-water, as salt as that which was just taken out of the sea. It seemed to have been drawn out of the sea, and thrown upon the land in the same hour: so that there was no time for that wonderful operation of nature, whereby the water that ascends in

clouds, is freed from its salt and bituminous particles, before it falls to the earth.

3. When the particles of water in a cloud are frozen, it occasions Snow, which floats in the air till it is driven together, so as to be heavy enough to sink. When the drops of rain in falling toward the earth, meet with a stream of cold air, they are often froze into ice, and so fall to the ground in the form of Hail. Hence the reason appears, why Snow, which is only frozen mist, is lighter than either Rain or Hail.

But why is Snow, though it seems to be soft, truly hard? Because it is true ice. It seems soft, because at the first touch of the finger on its sharp edges or points, they melt. Otherwise they would pierce the finger, just as so many lancets.

But why, though it be true ice, which is an hard and dense body, is it so very light? Because of the extreme thinness of each icicle, in comparison of its breadth. So gold, the most ponderous of all bodies, when beaten into leaves, rides upon the air.

Why is it white? Because its parts, though singly transparent, yet must appear white when mixed together: as do the parts of froth, of powdered glass, and other transparent bodies, whether soft or hard.

You will see Snow of a peculiar kind, if you try the following experiment. Set a tall phial of aqua fortis by the fire, till it is warm. Then put in filings of pure silver, a few at a time, and after a brisk ebullition, the silver slowly dissolves.

Place

Place this in a cold window. As it cools, the silver particles shoot into chrystals, several of which running together, form a flake of snow, and descends to the bottom of the phial. While they are descending, they perfectly represent a shower of silver Snow. And the flakes lie upon one another at the bottom, like real snow upon the ground.

Many particles of Snow are of a regular figure, like rowels, or stars of six points. On each of these points are other collateral stars, but many of the points are broken. Others have been thawed, and are froze again into irregular clusters. All these are perfect ice, so that the whole of Snow is an infinite number of icicles. A cloud of vapours condensing, forthwith descends, till meeting with a freezing air, each drop immediately becomes an icicle, shooting itself into several points. These descending still, and either striking on each other, or meeting with gales of warmer air, are a little blunted or thawed, and froze again into clusters, and so intangled as to fall in flakes.

Even in our temperate climate, we have sometimes had very extraordinary showers of Hail. On April 29, 1697, a thick black cloud, coming from Carnarvonshire, poured such an Hail on Cheshire, Lancashire, and some other counties, that in a line two miles broad and sixty miles long, it did inconceivable damage. It not only killed all small animals, but split trees, and beat down horses and men. The Hail-stones, many of which weighed five ounces, some seven or eight, were of various figures: some round, others half round, some smooth, others embossed, or variously granulated.

The icy substance of them was transparent and hard; but there was a snowy kernel in the middle of each.

May 4, in the same year, there was a shower of Hail, in Hertfordshire, which exceeded this. Fields of rye were cut down as with a scythe; several men killed, and vast oaks split. The stones were from ten to fourteen inches round, some oval, some picked, and others flat.

Mezeray relates that in Italy, in 1510, there was, after an horrible darkness, a shower of Hail which destroyed all the fish, birds and beasts of that country. It was attended with a strong smell of sulphur. Some of the stones weighed an hundred pounds.

4. The Rainbow is always seen in the region opposite to the sun, and never but when it rains on that side. Its colours are constantly in this order; the outermost red, the next yellow, the third green, the innermost violet colour: but these are not always equally vivid. When two Rainbows appear, the upper exhibits the same colours, but fainter, and in an inverted order. The seat of the Rainbow is the drops of Rain, on which the rays of the sun fall, and after various refractions and reflections, strike on the eye of the beholder. This is rendered indisputable from hence, that the very same colours, and in the same order, are exhibited in the drops of water, spouted from a fountain.

The Moon also sometimes exhibits a Rainbow; but only when she is full: her light being at other times too faint to affect the sight, after two refractions

tions and a reflection. It has all the colours of the solar Rainbow, very distinct and pleasant, only considerably fainter.

A Rainbow is likewise sometimes exhibited by the Sea, when a strong wind carries the tops of the waves aloft, and the sun's rays falling upon them are refracted and reflected, as in a shower. But the colours of this are less lively, less distinct, and less durable than those of the common Bow. Scarce above two colours are distinguishable, a dark yellow on the side next the sun, and a pale green on the opposite side. But sometimes 20 or 30 of them are seen at once. They appear at noon-day, in a position opposite to that of the common Rainbow, the concave side being turned upwards.

5. Halo's are circles of various colours, which are sometimes seen round the sun or moon. The space contained within them (especially near those parts which are tintured with the most lively colours,) is more dusky than the sky without. (They never appear in rainy weather.) Perhaps the air is at that time full of very small icy particles, on which the rays of the sun or moon falling, after refraction, exhibit that appearance.

6. As to Mock Suns, we sometimes see a large, white circle, parallel to the horizon, in several parts whereof more or fewer suns appear, though not always of the same size or colour. As an Halo frequently appears at the same time, it is probable they spring from much the same cause, namely, from icy particles floating in the air, be-

tween the sun and the eye of the spectator. The rays of the Sun reflected from these, may form that bright circle, in certain parts whereof, by a double refraction and reflection of them, those fictitious suns appear. In the same manner, the appearances termed Mock Moons may be accounted for.

7. Among Fiery Meteors are reckoned, Thunder, Lightning, Ignis Fatui, Lambent Flames, and what are called, Falling Stars. Unless we account for these (as indeed it is easy to do) upon the principles of electricity, we must suppose they are owing to sulphureous or bituminous particles, floating in the air, which when collected in sufficient quantities, take fire by various means. If a large quantity of inflammable vapour takes fire at once, the flame tears the cloud with incredible force, as well as immense noise. But the light moving swifter than the sound, is seen before that is heard. Sometimes an exhalation of a milder kind takes fire, and produces lightning without thunder. When it thunders and lightens, it commonly rains too, the same shock driving together and condensing the clouds. And the wisdom of God appoints it so, for the preservation of his creatures. For if lightning falls on one who is thoroughly wet, it does him no harm at all. Not that the water quenches or resists the fire; but it conveys it into the ground.

High places are most frequently struck with lightning, if they have sharp points, as spires of churches, or tops of trees, which, as it were, attract the fire. It sometimes burns the clothes without hurting the body; sometimes breaks the bones without scorching the skin. It melts the
sword

sword in the scabbard, or money in the pocket, while the scabbard or pocket remains as it was. In general, it passes innocently through those things that make little or no resistance; but tears those in pieces with impetuous force, which resist its passage.

One very peculiar effect of lightning, is what the vulgar call, Fairy Circles. These are of two kinds. One kind, is a round, bare path, about a foot broad, with green grass in the middle, and is frequently seven or eight yards in diameter. The other is a circle of the same breadth, of very green grass, much fresher than that in the middle. These are generally observed after storms of thunder and lightning. And it is no wonder, that lightning, like other fires, moves circularly, and burns more at the extremity than in the middle. The second kind of circles without all doubt spring originally from the first: the grass, which was burnt up by the lightning, growing afterward more fresh and green.

But of what kind was that Meteor which appeared March 21, 1676? Two hours after sun-set, it came over the Adriatic sea, from E. N. E. to W. S. W. and crossed over all Italy, being nearly vertical to Rimini on the one side, and Leghorn on the other. It was at least thirty-eight miles high. In all places near its course, it made a hissing noise like a sky-rocket. Having passed Leghorn, it gave a sound like that of a large cannon, and quickly after like a cart, running over stones. It was computed to move 160 miles in a minute, which is above ten times as swift as the diurnal motion of the earth. Its smaller diameter was

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judged

judged to be above half a mile. No wonder then, that so large a body, moving with such incredible swiftness through the air, though so much rarified, should cause that hissing noise. It is much harder to conceive, how such an impetus could be impressed upon it: how this impetus should be determined, in a direction so nearly parallel to the horizon? And what sort of substance it must be, that could be so impelled and ignited at the same time? Whatever it was, it sunk, and was extinguished in the Tyrrhene Sea, to the W. S. W. of Leghorn. The great noise was heard, on its immersion into the water, the rattling sound upon its quenching.

On Thursday, March 19, 1719, there appeared at London, about eight at night, a sudden great light, moving after the manner, but more slowly than a falling star, in a direct line, a little beyond, and withal below Orion's Belt, then in the south-west. In its way, it turned tapering upward, and at last spherical, near as big as the full moon. It was whitish, with an eye of blue, as bright as the sun in a clear day. It seemed in half a minute to move twenty degrees, and to go out, as much above the horizon. There remained after it for more than a minute, a track of a red-dish colour, such as that of red hot iron; and sparks seemed to issue from it, such as come from red hot iron, beaten upon an anvil.

Within doors the candles gave no light; and without, not only the stars disappeared, but the moon, nine days old, though the sky was clear, and she was then near the meridian: so that for some seconds, we had perfect day. Its height was seventy three miles and an half. Hence it
might

might be seen in all places, which were not distant from it more than two hundred and twenty leagues. Accordingly, it was seen at the same instant, over Spain, France, Great-Britain, Ireland, Holland, and the hither parts of Germany.

Another appearance, which resembles lightning is the Aurora Borealis, commonly called Northern Lights. This is usually of a reddish colour, inclining to yellow, and sends out coruscations of bright light, which seem to rise from the horizon in a pyramidical form, and shoot with great velocity up to the zenith. It appears frequently in the form of an arch, rises far above the region of the clouds, yet never appears near the equator, but always nearer the poles.

8. Vapours of the same kind, that give rise to lightnings in the air, occasion Damps in the earth. The Damps usual in mines are of four sorts. The approach of the first and most common is known by the flame of the candle lessening till it goes out: as also by the men's difficulty of breathing. Those who escape swooning are not much hurt by this: but those who swoon away, are commonly on their recovery seized with strong convulsions. The second is the Peasbloom Damp, so called because of its smell. This comes only in summer, and is common in the Peak of Derbyshire. They who have seen the third sort of Damp, describe it thus. In the highest part of the roof of those passages in a mine, which branch out from the main groove, a round thing hangs about as big as a foot-ball, covered with a thin skin. If this be broken, the Damp immediately spreads, and suffocates all that are near. But

sometimes they contrive to break it at a distance; after which they purify the place with fire. The fourth is the Fire-damp: a vapour, which if touched by the flame of a candle, takes fire, and goes off like gunpowder. And yet some who have had all their cloaths burnt off by one of these, and their flesh torn off their bones, at the very time felt no heat at all, but as it were a cool air.

Sir James Lowther, having collected some of this air in bladders, brought it up to London. Being let out at the orifice through a tobacco-pipe, it would take fire at the flame of a candle. And even this is imitable by art. Most metals emit sulphureous vapours, while they are dissolving in their several menstruums. Iron for instance, while it dissolves in oil of vitriol, emits much sulphureous vapour. If this be received into a bladder, and afterwards let out in a small stream, it takes fire, just in the same manner as the natural vapour.

This experiment explains one cause of earthquakes and volcanos; since it appears hence, that nothing more is necessary to form them, than iron mixing with vitriolic acid and water. Now iron is generally found, accompanied with sulphur; and sulphur consists of an inflammable oil, and an acid like oil of vitriol.

This acid in the bowels of the earth, being diluted with a little water, becomes a menstruum to iron, with a violent effervescence and an intense heat. The air coming from this mixture is extremely rarefied, and the more it is compressed by the incumbent earth, so much the more its impetus will be increased to an unlimited degree. Nor does there need fire to set these vapours to work.
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The air in the bladder, if it be much heated, will of itself take fire, as soon as it is brought into contact with the external air.

Other Damps are sometimes as mortal as those in mines. In the year 1701, a mason being at work in the city of Rennes, near the brink of a well, let his hammer fall into it. A labourer who was sent down for it, was suffocated, before he reached the water. A second, sent to draw him up, met with the same fate. So did a third. At last a fourth, half drunk, was let down with a charge to call out immediately, if he felt any inconvenience. He did call, as soon as he came near the water, and was drawn up instantly. Yet he died in three days, crying out, he felt a heat, which scorched his entrails. Yet the three carcases being drawn up with hooks, and opened, there appeared no cause of their death.

The same historians relate, that a baker of Chartres, having carried seven or eight bushels of brands out of his oven into a cellar 36 stairs deep, his son, a strong young fellow, going with more, his candle went out on the middle of the stairs. Having lighted it afresh, he no sooner got into the cellar, than he cried for help, and they heard no more of him. His brother, an able youth, ran down, cried, "I am dead," and was heard no more. He was followed by his wife, and she by a maid, and still it was the same. Yet an hardy fellow resolved to go and help them; he cried too, and was seen no more. A sixth man desired an hook to draw some of them out. He drew up the maid, who fetched a sigh and died. Next day one undertook to draw up the rest, and was let
I 6 down

down on a wooden horse with ropes, to be drawn up whenever he should call. He soon called, but the rope breaking, he fell back again, and was a while after drawn up dead. Upon opening him the membranes of the brain were found extremely stretched, his lungs spotted with blood, his intestines swelled as big as one's arm, and red as blood, and all the muscles of his arms, thighs and legs, torne and separated from their bones,

Whence this strange difference should arise, that the vapours of some mines catch fire with a spark, and others only with a flame, is a question that we must be content to leave in obscurity, till we know more of the nature both of mineral vapour and fire. This only we may observe, that gunpowder will fire with a spark, but not with the flame of a candle: on the other hand, spirits of wine will flame with a candle, but not with a spark. But even here the cause of this difference remains a secret.

A like instance of the fatal nature of foul air, happened at Boston in New England. Mr. Adams and his servant being employed to repair a pump, uncovered the well, and Mr. Adams went down by a rope; but he had not gone six feet, before he dropt suddenly without speaking a word, to the upper part of the joint of the pump, where being supported about a minute, and breathing very short, he then fell to the bottom, without any signs of life. His servant hastily went down, to help his master; but at the same distance from the top, was struck, and without discovering any signs of distress, fell to the bottom. The workmen prepared a third, with a tackle about his waste.

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On his descent, he was quickly speechless and senseless. Though he made no sign, they drew him up. He was the very picture of death, but by the use of proper means recovered. He remembered nothing of what had passed. The other bodies when taken up, had all the marks of a violent death.

The vapour* of fermenting liquors is equally extraordinary in its effects. This vapour appears over the fermenting liquor as a fog in a meadow, but more fleecy. It is heavier than air, and falls quick to the ground, and disappears. Van Helmont calls it, *Gas Sylvestre*. Boerhaave says, "There is nothing more surprising in fermentation, than that *Spiritus Sylvestris*, nor is there any poison that I am acquainted with, so subtle, swift, and fatal. For if a very large vessel, full of must, in the very act of fermentation, should discharge this spirit through a small vent-hole in the top of the vessel, and the stoutest man should apply his nose to the hole, and at once draw in this vapour, he would drop down dead in an instant, without any apparent cause of it. It extinguishes flame instantaneously. If a lighted candle be let slowly into it, the flame is borne up from the wick, and the candle may be raised up again so as to receive the flame." One put a mouse into it, which was killed in about a second of time, it kicked once or twice, and then was quite dead.

May we ascribe to a kind of Damp, a sort of murrain, which appeared in Italy, and made great havock among the cattle? It spread itself in the form of a blue mist, over those pastures where they grazed: so that whole herds came
home

home sick, and most of them died in twenty-four hours. Many who went among them, were infected, and died in the same manner. Some imputed this contagion to noxious vapours, thrown out of the earth, by earthquakes preceding. It passed through Germany to Poland, going without intermission, eleven or twelve miles in twenty-four hours, and suffering no cattle in its way to escape, whether within doors or without. Hence others imagined it was owing to some volatile insect, which was able to make but short flights.

9. Ignis Fatuus, vulgarly called Will with the Wisp, is chiefly seen in dark nights, irregularly moving over meadows, marshes, and other moist places. It seems to be a viscous exhalation, which being kindled in the air, reflects a kind of thin flame in the dark, though without any sensible heat. It is often found to fly along rivers or hedges, probably because it there meets with a stream of air to direct it. In Italy there are luminous appearances, nearly resembling these, which on a close inspection have been found to be no other than swarms of shining flies.

In all the territories of Bologna, these *fiery appearances* are common. There are some places where one may be almost sure of them, every dark night, as near the bridge Della Salcarata, and in the fields of Bagnara, these are large: sometimes equal to the light of a faggot, rarely less than that of a link. That at Bagnara not long since kept a gentleman company for a mile, moving just before him, and calling a stronger light on the road than the link he had with him.

All of them resemble a flame, and are continually in motion, but the motion is various and uncertain. In winter, when the ground is covered with snow, they are most frequent of all. Nor does rain hinder them: nay, in wet weather they give the strongest light: wind also does not disturb them. As they are not hindered by wet, and set nothing on fire, though ever so combustible, may it not reasonably be supposed, that they have some resemblance to that kind of Phosphorus, which shines indeed in the dark, yet does not burn like common fire?

The following experiments shew a little more of the nature of this strange substance.

Salt of Phosphorus, kept in a vitrifying heat, at last runs into perfect glass. What a wonderful subject is this? And how surprising it is, that so inflammable a body should become glass! Here then is a perfect transmutation of bodies: the Phosphorous being transmuted into a transparent glass of a bluish green, coming nearer the hardness of a diamond, than any other glass whatever. And the glass is in the very same quantity with the Phosphorus, which produces it ounce for an ounce.

Another odd circumstance relating to Phosphorus is, cut it small, or scrape it with a knife, and lay it on a glass dish in moist air. In a week it resolves into a liquid, near eighty times its original weight. This liquid is the same in all respects, with that which comes from the sublimed flowers by deflagation. And this may be turned into the same glass with the original Phosphorus.

One of the most singular kinds of *lambent Fires*, is that discovered at certain times on sea water. Where the ship goes swiftly in the night, in many seas the whole breaking of the water will appear behind it, as if on fire, sparkling and shining all the way that it moves from the ship.

It is in this part as bright and glittering as if the moon shone upon it, and chiefly when there is neither moon nor stars, nor any light in the lanterns. But it is not always the same; sometimes it is scarce perceivable, sometimes very vivid and bright. Sometimes it is only just behind the ship, sometimes it spreads a great way on each side. It commonly reaches thirty or forty feet from the stern of the ship, but is fainter as it is farther off. At the stern it is often so bright, that a person on deck may see to read by it. The luminous water that follows the ship is sometimes distinct from the rest of the surface. Sometimes it is so blended with the adjacent water, that the appearance is confused. The luminous matter seems composed of small sparkles, which are sometimes in the figure of a star, sometimes it forms globules, without any radiations from them. These are, some of the size of a large pin's head; some larger, even to a foot in diameter. Sometimes the luminous matter is in oblong squares, of three or four inches. When the ship goes swiftly, these figures all combine and form a sort of luminous whirlpool. Nor does a ship only, but whatever moves swift through the sea, cause the same appearance. Large fish when they swim near the surface, leave a luminous road behind them. So do a number of fish moving together. And sometimes the throwing out a rope, or any thing that breaks the surface of the water, will render it luminous. If
sea-

sea-water be taken up, and placed in a vessel, as soon as it is stirred, it will sparkle: and if a linen rag be dipped in sea-water, and hung up, when it is thoroughly dried, it will appear luminous on being rubbed in the dark; and when half dry, it need only be shook, to shew a great number of sparkles. When these sparkles are once formed, and fall on any solid body, they will last a considerable time. If they remain on the water, they will soon go out.

The waves beating against the rocks or shore, yea, or against one another, will occasion the same appearance, and often yield a long course of light the whole night. In the Brasils the shores often seem all on fire, by the waves dashing against them. In general, the thicker and fouler the seas are, the more of this light they afford. In many places the sea is covered with a yellowish matter like saw-dust, which seems to be the excrement of some sea-animal. The water where this is found, gives more light, upon moving, than any other.

Some parts of the northern seas are covered with this, for several leagues together, and this is often luminous all over in the night, though not stirred by any thing moving through it.

In the gulph of Venice the water is luminous, only from the beginning of summer till the end of harvest. This light is most copious in places abounding with sea-grass, especially when any thing moves the water. One filled a flask with this water; but it emitted no light till it was stirred in the dark. When this was strained through a fine cloth, the cloth shone in the dark, but not the

the water. This light consisted of innumerable lucid particles. When some of this sea-grass was taken up, there were above thirty of these particles on one leaf, one of which when it was shaken, fell off. It was as fine as an eye-lash and about as long. Viewed with a microscope it appeared to be a worm or maggot, consisting of eleven rings, with as many mamillæ on the sides instead of feet. Their whole bodies were lucid, though least so, when at rest. In spring they confine themselves to the sea-grass: but in summer they are dispersed all over the sea, and mostly on the surface. When this sea sparkles more than usual, it is the sure sign of a storm: and this proceeds from the greater agitation of the worms, already sensible of the approaching change. Hence it is clear, that the glittering of this sea, in a ship's course, is occasioned by these worms: which probably is the case in some other seas also. And they are certainly the cause of the light in the Pinna-Marina, a large muscle frequently caught by the Algerine fishermen.

Many Sea-fish indeed have a viscous matter about their gills, especially when they have been some time dead. These, when kept in sea-water, shine as bright as a flaming coal. A stick rubbed on their gills, becomes luminous wherever it has touched them, and continues so, while it continues moist; but as it dries, the light fades.

There is a small shell-fish, called a *Dactylus*, which is luminous all over. When it is taken out of the shell, in the dark, every part of its surface shines with a bright light. Nor is it the surface only; but the whole body. For if it be wounded

wounded either lengthways or across, the out parts were as luminous as the surface. It is therefore a true, natural phosphorus, and makes every thing luminous that touches it, which remains so as long as it is wet. When it is fresh caught it abounds with water, and the very drops which fall from it are luminous.

Some boiled Mackrel having been left in the water for pickle, the cook, a day or two after, stirring the water, found it very luminous. Wherever the drops of it fell on the ground they shined. The next day we repeated the trial. The water 'till stirred, gave no light; but when gently stirred by the hand, it shone bright; and by a brisker motion it seemed to flame. The fish shone, as well from the inside as the out: yet they were not either fetid or insipid. When fetid, they did not shine at all.

The chief circumstances which Mr. B. noted concerning *luminous flesh* were, 1. It was a neck of veal, bought some days before: 2. In this about twenty places shone, though not alike: 3. Most of these were as big as the nail of a man's finger, and irregularly shaped: 4. The parts which shone most were the grisly, or the bruised parts of the bones; 5. Some of these were so bright, that holding a printed paper to them, I could read several letters: 6. One could not discern in any of them the least degree of heat, neither of putrefaction: 7. One of these being put in a cup of cold water, the light continued the same.

Not only water, fish and flesh, but some sort of wood will shine as bright as a burning coal. And herein they agree, 1. Both have light in themselves: 2. Both need the air, to make them continue shining: 3. Both having lost their light, by
being

being deprived of air, recover it, when fresh air is let in: 4. Both are easily quenched by water, and 5. Neither of them is affected by the coldness of the air.

But herein they differ: 1. The light of a coal is put out by compression: that of wood is not: 2. The coal is quite extinguished by withdrawing the air: that of the wood is only eclipsed: let the air in again within half an hour, and it immediately recovers: 3. A coal put into a small, close glass, will not burn many minutes: a piece of wood will shine many days: 4. A burning coal emits much smoke, shining wood none at all.

A diamond, by an easy friction in the dark, by the finger or a woollen cloth, appears in its whole body to be luminous: and if it has been rubbed a good while, it will keep its light for a little time. If when the sun is set, one hold up a piece of flannel stretched tight between both hands at a little distance, and another rubs the diamond swiftly and strongly on the other side of it, the light to the eye of him that holds the cloth, seems much more pleasant and perfect. What is more surprising, is, that a diamond exposed to the open air, in view of the sky, (even without being in the sunshine) gives nearly the same light of itself without rubbing, as when rubbed in a dark room. But if you hold your hand or any thing else over it, to hinder its communication with the sky, let it lie ever so long in the open air, yet it will give no light.

A well-polished piece of Amber, will yield light, if rubbed in the dark. And if it be drawn swiftly

swiftly through a woollen cloth, very many little cracklings are heard, and each produces a little flash of light. If drawn gently it produces a light, but no crackling.

The following is the most satisfactory account I have ever seen of this phenomenon.

The splendor of the sea-water during the night, hath long been a subject of admiration, and upon the coasts of Chioggia it is particularly remarkable: at first sight one would imagine that the brilliant images of the fixed stars were reflected by the sea, when agitated by the winds. This brightness becomes much more vivid and copious, in places abounding with the *Alga Marina*, or Sea Weed.

One summer-night I took a vessel full of the sea water home with me. I placed it in a dark room, and observed as often as I disturbed the water, a very bright light issued from it. I then passed the water through a very close linen cloth, to try if it would still retain its splendor after such percolation. But notwithstanding I agitated it in the most violent manner, I could not excite the least luminousness in it. The linen cloth however afforded the most charming spectacle imaginable: it was covered with an infinity of lucid particles. To the naked eye they appear smaller than the finest hairs: their colour of a deep yellow, and their substance delicate beyond imagination: but having a mind to examine them more curiously, I furnished myself with a good microscope, and was soon convinced that these luminous atoms are really living animals of a very singular structure, and from the brightness of their lustre, I thought myself authorised to name them *Marine Glow-Worms*.

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These little animals, similar to caterpillars, and other insects of that species, are composed of eleven articulations, or annuli, a number which, according to the celebrated Malpighi, is peculiar to the whole vermicular race. Upon these annuli, and near the belly of the animal, are a sort of small fins or wings, which seems to be the instruments of its motion. It has two small horns issuing from the fore part of its head, and its tail is cleft in two. Their whole body is luminous, and when cut to pieces, every piece emits a vivid light for some time ; probably so long as the convulsive motion of the dying parts continues.

Many philosophers of the first rank have imagined that the luminousness of the sea-water in the night season is occasioned by some electric matter. " The surface of the sea, say they, having been exposed all the summer to the impulse of the solar rays, when it begins to be agitated by the autumnal winds, throws out luminous sparks perfectly similar to those which issue from electrified bodies."

But ocular demonstration now convinces us, that this brightness is to be ascribed to these little animals.

The light of a Glow-worm is so strong, that it will shew itself through several substances. The creature seems dead in the day-time, and its light is not then visible even in a dark room, unless it be put in motion, and then it is very faint. After sun-set the light begins to return, and with it the life and motion of the animal. Indeed, the motion and light seem to depend on each other: it never shines, but when it moves: and when it shines most, the body is one third longer than in
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the day-time. While it shines brightest, it sometimes turns about, and the light is no larger than a pin's head. But on being touched, it immediately extends itself, and the light is as large and bright as ever.

The luminous parts are two small specks under the tail. The use of this light is, to direct the animal in its course, and in taking of its prey. It is admirably placed for this purpose. The tail is easily bent under its belly, and throws its light full upon any object, about or under the head of the animal, and the eyes are placed not on the upper part, but on the under side of the head, so that they have all the advantages of it, while the light in this part is not offensive to the eyes, as it naturally would have been, if carried about the head. The creature can upon occasion cover this light, so as not to be known, or pursued by its enemies. It is an insect of the beetle-kind, of a brown and dusky colour. It has shell wings as the other beetles have. Its head is covered with a sort of broad-brimmed hat, under which are the eyes which are black and large.

Falling Stars, so called, seem to be vapours of an unctuous kind, kindled in the lower regions of the air: unless this also (as many other phænomena of the sort) be owing to what is vulgarly termed Electricity.

10. From a thousand experiments it appears, that there is a fluid far more subtle than air, which is every where diffused through all space, which surrounds the earth, and pervades every part of it. And such is the extreme fineness, velocity, and expansiveness of this active principle, that all other matter seems to be only the body, and this the soul of the universe.

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It is highly probable this is the general instrument of all the motion in the universe : from this *pure fire*, (which is properly so called) the vulgar *culinary fire* is kindled. For in truth, there is but one kind of fire in nature, which exists in all places, and in all bodies. And this is subtle and active enough, not only to be under the great Cause, the secondary cause of motion, but to produce and sustain life throughout all nature, as well in animals as in vegetables.

This great machine of the world, requires some such constant, active, and powerful principle, constituted by its Creator, to keep the heavenly bodies in their several courses, and at the same time give support, life, and increase to the various inhabitants of the earth. Now as the heart of every animal is the engine which circulates the blood through the whole body, so the Sun, as the heart of the world, circulates this fire through the whole universe. And this element is not capable of any essential alteration, increase, or diminution. It is a species by itself ; and is of a nature totally distinct from that of all other bodies.

That this is absolutely necessary both to feed common fire, and to sustain the life of animals, may be learned from an easy experiment. Place a cat, together with a lighted candle, in a cold oven : then lute the door close, having fixed a glass in the middle of it ; and if you look through this, you may observe at one and the same instant, the candle goes out, and the animal dies. A plain proof, that the same fire is needful to sustain both culinary fire and animal life : and a large quantity of it. Some doubtless pervades the oven-door ; but not enough to sustain either flame or life. Indeed, every animal is a kind of fire-engine

gine. As soon as the lungs inspire the air, the fire mingled with it is instantly dispersed through the pulmonary vessels into the blood: thence it is diffused through every part of the body, even the most minute arteries, veins and nerves. In the mean time the lungs inspire more air and fire, and so provide a constant supply.

The air seems to be universally impregnated with this fire, but so diluted, as not to hurt the animal in respiration. So a small quantity of a liquor dropt in water may be friendly to an human body, though a few drops of the same liquor given by themselves, would have occasioned certain death. And yet, you cannot conceive one particle of the water, without a particle of the medicine. It is not impossible, this may be one great use of air, by adhering so closely to the elementary fire, to temper and render salutary to the body, what would otherwise be fatal to it.

To put it beyond dispute, that this Fire is largely mixed with the air, you may make the following experiment. Take a round lump of iron, and heat it to a degree called a *welding* heat: take it out of the fire, and with a pair of bellows, blow cold air upon it. The iron will then as effectually melt, as if it were in the hottest fire. Now when taken out of the forge, it had not fire enough in it to conquer the cohesion of its parts: but when this fire is joined with that which was mixed with the air, it is sufficient to do it. On the same principle we account for the increase of a coal or wood fire, by blowing it.

And let none wonder, that Fire should be so connected with air, as hardly to be separated. As

subtle as Fire is, we may even by art attach it to other bodies; yea, and keep it prisoner for many years: and that, either in a solid or fluid form. An instance of the first we have in steel; which is made such, only by impacting a large quantity of fire into bars of iron. In like manner, we impact a great quantity of fire into stone to make lime. An instance of the second kind we have in spirits, wherein fire is imprisoned in a fluid form. Hence common spirits will burn all away. And if you throw into the air, spirits rectified to the highest degree, not one drop will come down again, but the universal Fire will take hold of and absorb it all.

That this fire subsists both in air, earth, and water: that it is diffused through all and every part of the universe; was *suspected* by many of the ancient naturalists, and *believed* by the great Sir Isaac Newton. But of late years it has been fully demonstrated: particularly, by Mr. Stephen Gray, a Pensioner at the Charter-house: who some years since presented to the Royal Society, an account of many experiments he had made, whereby this subtle fluid became clearly perceptible both to the sight and feeling. Because the glass tube, by means of which those experiments were made, was observed when rubbed to attract straws and other light bodies (a known property of amber, called in latin *Electrum*) these experiments were termed *Electrical*: a word which was soon affixed to that subtle fluid itself, and every thing pertaining to it. But improperly enough: seeing the attracting (or seeming to attract) straws and feathers, is one of the most inconsiderable of all the effects, wrought by this powerful and universal Cause.

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It was afterwards found, that a glass globe was preferable to a glass tube. A greater quantity of ethereal fire is *collected* by this means, than by the other. I say, *collected*; for that fire is no more *created* by rubbing, than water is by pumping. The grand reservoir thereof is the earth, from which it is diffused every way. Accordingly in these experiments, the globe rubbing against the cushion, collects Fire from it. The cushion receives it from the frame of the machine; the frame of the machine from the floor. But if you cut off the communication with the floor, far less Fire can be *produced*, because less is *collected*.

Many new discoveries have been made by means of a large, but thin glass phial. This phial is hung on any metallic body, which communicates by a wire, with the globe. This metallic body has been termed, *the prime conductor*, as it conducts or conveys the Fire, collected by the globe, either into the phial, or into any other body communicating therewith.

But all bodies are not capable of receiving it. There is in this respect an amazing difference between them. The excrements of nature, as wax, silk, hair, will not receive the ethereal Fire, neither convey it to other bodies: so that, whenever in circulating it comes to any of these, it is at a full stop. Air itself is a body of this kind; with great difficulty either receiving or conveying this Fire to other bodies: so are pitch and rosin (excrements, as it were, of trees.) To these we may add glass, amber, brimstone, dry earth, and a few other bodies. These have been frequently stiled

Electrics per se; as if they alone contained the *Electric Fire*: an eminently improper title, founded on a palpable mistake. From the same mistake, all other bodies, which easily receive and readily convey it, were termed *Non-Electrics*; on a supposition, that they contained no *Electric Fire*: the contrary of which is now allowed by all.

That this Fire is inconceivably subtle, appears from its permeating even the densest metals, and that with such ease, as to receive no perceptible resistance. If any one doubt, whether it pass through the substance, or only along the surface of bodies, a strong shock taken through his own body, will prevent his doubting any longer. It differs from all other matter in this, that the particles of it repel, not attract each other. And hence is the manifest divergency in a stream of Electrical Effluvia. But though the particles of it repel each other, yet are they attracted by all other matter. And from these three, the extreme subtlety of this Fire, the mutual repulsion of its parts, and the strong attraction of them by other matter, arises this effect, that if any quantity of Electric Fire be applied to a mass of common matter of any bigness or length, (which has not already got its quantity) it is immediately diffused through the whole.

It seems this globe of earth and water, with its plants, animals, buildings, have diffused through their whole substance, just as much of this Fire as they will contain. And this we may term their *natural quantity*. This is not the same in all kinds of matter: neither in the same kind of matter,

matter, in all circumstances. A solid foot of one kind of matter (as glass) contains more of it than a solid foot of another kind. And a pound weight of the same kind of matter, when rarefied, contains more than it did before.

We know that this Fire is *in* common matter, because we can pump it *out* by the globe: we know that common matter has near as much of it as it can contain, because if we add a little more to any portion of it, the additional quantity does not enter, but forms a kind of atmosphere round it. On the other hand we know, that common matter has not more of it than it can contain. Otherwise all loose portions of it would repel each other; as they constantly do, when they have such atmospheres. Had the earth, for instance, as much Electric Fire in proportion, as we can give to a globe of iron or wood, the particles of dust and other light matter, would not only repel each other, but be continually repelled from the earth. Hence the air, being constantly loaded therewith would be unfit for respiration. Here we see another occasion to adore that wisdom, which has made all things by weight and measure.

The form of every electric atmosphere, is that of the body which it surrounds: because it is attracted by every part of the surface, though it cannot enter the substance already replete. Without this attraction, it would not remain round the body, but dissipate into the air.

The atmosphere of an electrified sphere, is not more easily drawn off, from any one part of it than from another, because it is equally attracted by every part. But it is not so with bodies of

other figures. From a cube it is more easily drawn off at the corners than at the sides: and so from the corners of bodies of any other form, and most easily from the sharpest corners. For the force with which an electrified body retains its atmosphere, is proportioned to the surface on which that atmosphere rests. So a surface four inches square retains its atmosphere, with sixteen times the force that one of an inch square does. And as in pulling the hairs from a horse's tail, a force insufficient to pull off an handful at once, could easily pull it off hair by hair: so though a blunt body cannot draw off all the atmosphere at once, a pointed one can easily draw it off, particle by particle.

While the Electric Fire, which is in all bodies, is left to itself, undisturbed by any external violence, it is more or less dense, according to the nature of the body which it is in. In dense bodies it is more rare: in rare bodies it is more dense. Accordingly every body contains such a quantity of it, rare or dense, as is suitable to its nature. And there is some resistance to every endeavour of altering its density, in the whole of any body, or in any part of it. For all bodies resist either the increase or diminution of their natural quantity. And on the other hand, when it has been either increased or diminished, there is a resistance to its return to its natural state.

With regard to the different resistance made by different bodies, in either of these cases, it is an invariable rule, that glass, wax, rosin, brimstone, silk, hair, and such like bodies, resist the most: and next to these, the air, provided it be dry,

dry, and in a sufficient quantity. That this resistance is least in metals, minerals, water, animals, and vegetables: which we may rank together, because the difference in their resistance is very inconsiderable: and that in these bodies the resistance is greater, when their surfaces are polished, and extended in length, than when their surfaces are rough and short, or end in sharp points.

When a body has more Electric Fire forced into it, than it has naturally, it is said to be electrified *positively*. When part of the natural quantity is taken away, it is said to be electrified *negatively*. Now when an iron bar is *negatively* electrified, the fire drawn out, does not go in again as soon as the experiment is over, but forms an atmosphere round it, because of the resistance it finds in its endeavour to dilate itself, either into the air, or into the bar. And when it is electrified *positively*, the same kind of atmosphere is formed, by the fire accumulated upon it. Whether therefore bodies are electrified *negatively* or *positively*, and remain so when the experiment is over, there are similar atmospheres surrounding them, which will produce similar effects.

But we can electrify no body beyond a certain degree; because when any is electrified to that point, it has an atmosphere round it, sufficiently strong to balance any power that endeavours to electrify it farther.

And in the ordinary course of nature, this subtle, active fluid, which not only surrounds every gross body, but every component particle of each, where it is not in absolute contact with its neighbouring particle, can never be idle, but is ever in action, though that action be imperceptible to our

senses. It is ever varying its condition, though imperceptibly, in all parts of all bodies whatever; and electrifying them more or less, though not so forcibly as to give sensible signs of it. All bodies then, and all their component particles, when in their natural situation, have round their surfaces, where they are not in absolute contact with other surfaces, an imperceptible atmosphere, sufficient to balance the smaller force with which they are attacked: every way similar to the perceptible atmosphere of bodies forcibly electrified. In these imperceptible atmospheres is placed the power which resists their being electrified to an higher degree than they are naturally. And this power lies in the elasticity of the subtle fluid, every where dispersed both round all bodies and in them.

Glass is very difficultly electrified, which seems to prove it has a very dense electric atmosphere. Metals are easily electrified. Consequently they have rare, and therefore weakly resisting atmospheres. But as heat rarefies all bodies, so if glass be heated to a certain degree, even below melting it will give as free a passage to the Electric Fire, as brass or iron does: the atmosphere round it being then rendered as rare as that of metals. Nay, when melted, it makes no more resistance than water. But its resistance increases, as it cools. And when it is quite cold, it resists as forcibly as ever. Smoothly-polished wax, resists as much as glass. But even the small heat raised by rubbing, will render its atmosphere as rare as that of metals, and so intirely destroy its resistance. The same is true of rosin and brimstone. Even the heat arising from friction, destroys the resistance

ance which they naturally make to being electrified: a strong proof, that the resistance of all bodies thereto, is exerted at their surfaces, and caused by an electric atmosphere of different densities, according to the different circumstances.

Most experiments will succeed as well with a globe of brimstone, as with one of glass. Yet there is a considerable difference in their nature. What glass repels, brimstone (as also rosin) attracts. Rubbed glass emits the electric fire: rubbed brimstone, rosin and wax receive it. Hence if a glass globe be turned at one end of a prime conductor, and a brimstone one at the other, not a spark of Fire can be obtained; one receiving it in, as fast as it is given out by the other. Hence also if a phial be suspended on the prime conductor, with a chain from its coating to the table, and only one globe turned, it will be electrified (or *charged* as they term it) by twenty turns of the wheel: after which it may be *discharged*, that is, *unelectrified*, by twenty turns of the other wheel.

The difference between *Non Electrics* (vulgarly speaking) and *Electrics per se*, is chiefly this. 1. A *Non Electric* easily suffers a change, in the quantity of Fire it contains. Its whole quantity may be lessened, by drawing out a part, which it will afterwards resume. But you can only lessen the quantity contained in one of the surfaces of an *Electric*: and not that, but by adding at the same time an equal quantity to the other surface. So that the whole glass will always have the same quantity in its two surfaces. And even this can be only done in glass that is thin: beyond a certain thickness, we know no power that can make this

change. 2. The Ethereal Fire freely moves from place to place, in and through the substance of a non-electric, but through the substance of an Electric it will by no means pass. It freely enters an iron rod, and moves from one end to another, where the overplus is discharged. But it will not enter, or move through a glass rod. Neither will the thinnest glass which can be made, suffer any particle of it entering one of its surfaces, to pass through to the other.

Indeed it is only metals and liquids, that perfectly *conduct* (or transmit) this Fire. Other bodies seem to conduct it, only so far as they contain a mixture of these; accordingly, moist air will conduct it in proportion to its moistness. But dry air will not conduct it at all: on the contrary, it is the main instrument, in confining any electric atmosphere to the body which it surrounds. Dry air prevents it dissipating (which it does presently when *in vacuo*) or passing from body to body. A clear bottle full of air, instead of water, cannot be electrified. But exhausted of air, it is electrified as effectually as if it was full of water. Yet an Electrical atmosphere and air, do not exclude one another. For we breathe in it freely, and dry air will blow through it, without altering it at all.

When a glass phial is electrified, whatever quantity of Fire is accumulated on the inner surface, an equal quantity is taken from the outer. Suppose, before the operation begins, the quantity of fire contained in each surface, is equal to twenty grains: suppose at every turn of the globe, one grain is thrown in: then after the first stroke there are twenty one within, nineteen only without: after the second, the inner surface will have
twenty

twenty-two, the outer but eighteen : and so on, till after twenty strokes, the inner will have forty, the outer none . And the operation ends : for no power or art of man can throw any more on the inner surface, when no more can be taken from the outer. If you attempt to throw more in, it is thrown back through the wire, or flies out in cracks, through the sides of the phial. The equilibrium cannot be restored in this phial, but by a communication formed between the inner and outer surface, by something external, touching both the outer, and the wire, which communicates with the inner surface. If you touch these by turns, it is restored by degrees : if both at once, it is restored instantly. But then there is a shock occasioned by the sudden passing of the fire through the body, in its way from the inner to the outer surface. For it moves from the wire to the finger, (not from the finger to the wire, as is commonly supposed.) Thence it passes through the body to the other hand, and so to the outer surface.

The force with which this shock may be given, is far greater than one would conceive. It will kill rats, hens, or even turkeys in a moment : others that are not quite killed, it strikes blind. It will give polarity to a fine needle, making it point north and south, as if touched by a loadstone. It will invert the polarity of a compass, and make the north point turn to the south. At the same time the ends of the needles are finely blued, like the spring of a watch. It will melt off the heads and points of pins and needles, and sometimes the whole surface of the needle is

run, and appears, as it were, blistered, when examined by a magnifying glass. It will melt thin gold or silver, when held tight between two panes of glass, together with the Surface of the glass itself, and incorporate them in a fine enamel. Yea, a strong spark from an electrified phial makes a fair hole through a quire of paper doubled: which is thought good armour against the push of a sword, or even a pistol bullet. And it is amazing to observe in how small a portion of glass, a great electrical force may be. A thin glass bubble, about an inch diameter, being half filled with water, partly gilt on the outside, when electrified gives as strong a shock, as a man can well bear: allowing then that it contains no more fire after charging then before, how much Fire must there be in the small glass? It seems to be a part of its very substance. Perhaps if that Fire could be separated from it, it would be no longer glass. It might in losing this, lose its most essential property, its transparency, brittleness, and elasticity.

Some have not improbably supposed, that all *Electric* bodies, so called, are by their original constitution, thoroughly saturated with Electric Fire: that it remains fixed in them, (unless while the texture of those bodies is quite altered by liquefaction) that Fire fixed in a body constitutes an *Electric*, and all bodies where it is not fixed are *Non Electrics*. Agreeably to which they suppose, that in all *Non Electrics*, the original Fire loosely inhering, is easily driven on by the new collected Fire, which then possesses its place: but that in *Electrics*, the original Fire being impacted into their substance, and therefore more firmly inhering, will not give way to, or be driven on by,

by, the new collected fire. Such is air in particular; with the particles of which the original Fire is closely incorporated. Dry air seems to be so fully saturated with it, that it is scarce capable of receiving any more: whereas all new-collected Fire is continually endeavouring to return into the earth. Let wires be electrified ever so strongly, yet the moment any part of them is touched by a person standing on the floor, they are electrified no longer; all the fire escaping through him into the earth.

Upon the principles of Electricity, we may give a more rational account of many appearances in nature, than has yet been done: of thunder and lightning in particular. In order to which we may observe, all electrified bodies retain the Fire thrown into them, till some non-electric approaches: to which it is then communicated with a snap, and becomes equally divided. Electric Fire is strongly attracted by water, and readily mixes with it. And water being electrified, the vapours arising from it, are equally electrified. As these float in the air, they retain the additional Fire, till they meet with clouds, not so much electrified. Then they communicate it with a shock.

The ocean is compounded of water and salt; one an electric, the other not. When there is a friction among the parts near its surface, the Fire is collected from the parts below. It is then plainly visible in the night, at the stern of every sailing vessel. It appears from every dash of an oar: in storms the whole sea seems on Fire. The particles of water then repelled from the electrified surface,

surface, continually carry off the Fire as it is collected. They rise and form clouds which are highly electrified, and retain the Fire, till they have an opportunity of discharging it.

Particles of water rising in vapours, attach themselves to particles of air. One particle of air may be surrounded by twelve particles of water as large as itself, all touching it, and by more added to them. Particles of air thus loaded would be drawn nearer together by the mutual attraction of the particles of water, did not the fire, common or electric, included therein, assist their mutual repulsion. Hence they continue suspended. But if air thus loaded, be compressed by adverse winds, or by being driven against mountains, or if it be condensed by the loss of its fire, it will continue suspended no longer, but will descend in dew. And if the water surrounding one particle of air comes into contact with that surrounding another, they naturally coalesce into a drop, and so descend in rain.

The Sun supplies Common Fire to all Vapours rising either from sea or land. Vapours having both this and Electric Fire, are better supported than those which have this only. For when Vapours rise into the coldest region, the common fire may fail. But the cold will not diminish the electric: this is always the same. Hence clouds raised from fresh waters, from moist earth, or growing vegetables, more easily descend and deposit their waters, as having but little electric fire, to keep the particles separate from each other. So that the greatest part of the water raised from the land, falls on the land again. But clouds
raised

raised from the sea, having both fires, and much of the electric, support their water far more strongly, and being assisted by winds, may bring it from the middle of the widest ocean to the middle of the broadest continent. And yet a way is provided whereby these also are readily brought to deposit their water. For whenever they are driven against mountains by the winds, those mountains take away their electric fire: and being cold, the common also: hence the particles immediately close. If the air was not much loaded, the water falls in a dew on the top and the sides of the mountain. If it was, the Electric Fire being taken at once from the whole cloud, it flashes brightly, and cracks loudly. And the particles instantly coalescing for want of that fire, fall in an heavy shower.

When a ridge of mountains stops the clouds, and draws the Electric Fire from the cloud first approaching it; the next, when it comes near the first, now deprived of its fire, flashes into it, and deposits its own water. The third cloud approaching, and all that succeed, act in the same manner, as far back as they extend, which may be for several hundred miles. Hence the continual storms of thunder, lightning, and rain, on the east side of those vast mountains, the Andes, which, running north and south, intercept all the clouds brought against them from the Atlantic Ocean. In a plain country, there are other means to make them drop their water. For if an electrified cloud, coming from the sea, meets in the air a cloud coming from the land, and therefore not electrified, the first will give its flash into the latter, and thereby both will be made to deposit

posit their water. The concussion of the air contributes also to shake down the water, not only from those two clouds, but from others near them. When the sea and land clouds would pass at too great a distance from each other, they are mutually attracted, till within the distance. For the sphere of Electrical Attraction is far beyond the flashing distance. And yet where a cloud contains much fire, it may strike at a considerable distance. When a conductor has but little fire in it, you must approach very near before you can draw a spark. Throw into it a greater quantity of fire, and it will give a spark at a greater distance. But if a gun barrel, when electrified, will strike and make a noise at the distance of an inch, at what a distance, and with how great a noise, may ten thousand acres of electrified cloud strike? No wonder that this should melt metals, (which our artificial flash does in some degree,) though perhaps not so properly by its heat, as by insinuating into the pores, and creating a violent repulsion between the particles of the metal it passes through. This overcomes the attraction whereby they cohere, and so melts the metallic body. And this accounts for its melting a sword in the scabbard, or gold in the pocket, without burning either.

But thunder-clouds do not always contain more than their natural quantity of Electric Fire. Very frequently they contain less. And when this is the case, when they are negatively electrified, although the effects and appearances are nearly the same, yet the manner of operation is different. For in this case, it is really the fire from the mountains, or other parts of the earth, which strikes into the cloud; and not, as we imagine,
fire

fire from the cloud which strikes into the earth. And we may easily conceive, how a cloud may be negatively electrified. When a portion of water is rarefied into a thin vapour, the fire it contains is rarefied too. Consequently it has then less than its natural quantity of fire. Such a cloud therefore coming within a due distance of the earth, will receive from it a flash of Electric Fire; which flash, to supply a great extent of cloud, must often contain a great quantity of fire. Such a cloud also passing over woods of tall trees, may silently receive some supply, either from the points of the boughs, or from the sharpest ends and edges of the leaves. The cloud thus supplied, flashes into other clouds that have not been so supplied; and those into others, till an equilibrium is produced, among all that are within a striking distance of each other. And hence are repeated strokes and flashes, till they descend in showers to the earth, their original. Rain, especially when in large drops, generally brings down the Electric Fire: falling snow, often: summer hail, always, though silently. Consequently any of these may prevent thunder and lightning; or, at least, abate its violence. Rain is helpful in another respect likewise. By wetting men or beasts, it saves many lives. For if your cloaths are thoroughly wet, and a flash of lightning strikes the top of your head, it will run in the water over the surface of your body into the ground: whereas if your cloaths were not wet, it would go through your body. Hence a wet chicken cannot be killed by a stroke from the phial; whereas a dry one is killed in an instant. See here also the wisdom and goodness of Him, *who sendeth forth lightning with the rain!* It should likewise

likewise be observed, that wherever electrified clouds pass, spires, towers, chimneys, and high trees, as so many points, draw the Electric Fire, and the whole cloud frequently discharges there. Therefore it is highly dangerous in such a storm, to take shelter under a tree.

Common Fire is more or less in all bodies, as well as Electrical. If there be a sufficient quantity of either in any body, it is inflamed. But when the quantity of Common Fire therein is small, there needs more Electric Fire to inflame it. Where the quantity of Common Fire is greater, less of the Electric will suffice. So if spirits are heated, a small spark inflames them. If they are not, the spark must be greater. Sulphureous vapours, whether rising from the earth, or from stacks of moist hay or corn, or any other heated and reeking vegetable, contain abundance of Common Fire. A small addition of Electric then will inflame them. Therefore they are easily kindled by lightning.

Any who would be clearly convinced of the nature of Lightning, may make the following experiment. Make a small cross of two thin strips of wood, the arms being just so long as to reach the four corners of a large, thin silk handkerchief when extended. Tie the corners of this to the extremities of the cross; and so you have the body of a kite: add to this a proper tail, loop, and string, and it will rise in the air like one made with paper: but this is fitter to bear the wind and wet in a storm without tearing. To the top of the cross fix a sharp-pointed wire, rising a foot above it. Tie a silk ribbon to the end of
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the twine next the hand; and where the silk and twine join, fasten a key. Raise this kite when a Thunder-storm is coming on. But he that holds the string, must stand in a porch, or under some other covering, that the ribbon may not be wet. He must likewise take particular care, that the twine do not touch the top or side of the porch. As soon as the Thunder-cloud comes over the kite, the pointed wire draws the Electric Fire from it. The kite and all the twine are then electrified, as plainly appears by this, that the loose filaments of the twine stand out every way, and are attracted by an approaching finger. And when the kite and twine being wet, conduct the Fire freely, it will stream from the key, on the approach of the knuckle. By this key the phial may be charged, and all other experiments made, as by the globe. And this is a demonstration, that the Electric Fire thereby obtained, is the very same with that of Lightning.

Another proof of this we have, in the remarkable case of the Rev. Mr. Winder, Rector of Halsted, in Essex; who at the age of fifty-four was a stranger to disease; nay, almost unacquainted with pain of any kind. But on June 3, 1761, he began to falter in his speech. He did not regard it, till on July 1, he suddenly fell from his chair, by a stroke of the palsy. When a little recovered, he was almost wholly deprived of speech, and in great measure of his senses. But by proper medicines he was in a few weeks so far restored, as to walk a little by the help of a cane. In other respects he was as before, till in June 1762 he was removed to Tunbridge. After drinking the waters six weeks, he was much relieved: but
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an universal weakness still remained. He had also violent palpitations of the heart, tremblings of the limbs, subultusteordinum; with frequent vertigos. Worse than all was, a constant pain fixed deep in his breast, with an extreme dejection of spirit. Thus he continued till the 24th of August: when about ten at night, while he was asleep in bed, it began to thunder and lighten violently. The noise suddenly awakened him. At the instant he felt a quick, strong shock, affecting him all over, just like an electric shock. At the same time the chamber was filled with lightning, which left behind it a strong phosphorous smell. Immediately he felt as if some obstruction in his chest was suddenly removed; and his breast recovered its full liberty and expansion, the oppression being entirely gone. When he arose in the morning, he was in perfect health: his head was quite serene; his breast easy, and he could move all his limbs with as much steadiness and agility as ever. Every paralytic symptom was gone. He could have walked ten or twelve miles with ease. And from that very hour he has continued in a state of perfect health.

What a clear proof this, that the Fire of Lightning has the same nature and force with the Electric?

The Gymnotus, of South-America, appears to possess Electrical Powers greatly superior to those of the European Torpedo. Some of them have been seen in the Surinam river upwards of twenty feet long, whose stroke was instantly fatal. That on which the following experiment was made, was three feet seven inches long, and was brought from Guiana to Philadelphia.

On

On putting a small fish into the vessel in which it swam, it was suddenly stunned and killed by it. The effect was evidently produced by a concussion, which was felt by one whose fingers were dipped in the water, at the very moment the fish was shocked by it. Eight or ten persons, forming a circle, were all shocked by it, when the first in the series touched the eel, and the last put his hand into the water. The commotion given by it, was conveyed through the same metallic or other conductors, as convey the Electric Fluid; and was intercepted by the common non-conductors of that fluid. Whatever therefore be thought of the Torpedo, it is plain this Eel is an Electric Machine, and has the power of suspending or giving the Electric Shock, just at its own pleasure.

Electricity has something in it common, both with Light and with Magnetism. In common with Magnetism it counteracts, and in light substances overcomes the force of gravity. Like that, it exerts its force *in vacuo*, as powerfully as in the open air. And this force extends to a considerable distance, through various substances of different textures and densities.

In common with Light, Electricity pervades glass; but it suffers no refraction. Its direction is still in right lines, and that through glasses of different forms, included one within the other, and large spaces left between them.

Indeed the electric attraction through glass, is much more powerful, when the glass is made warm: because warm glass does not condense the water from the air, which makes the glass a conductor of Electricity: and also because as heat enlarges
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the dimensions of all known bodies, and consequently makes their constituent parts recede from each other, the electric effluvia finds a more easy passage through the pores.

And Electricity in common with Light, when its forces are collected, produces fire and flame.

That the electric matter is far more subtle than air, appears, from its passing through those bodies which air cannot penetrate; glass in particular. And that it is elastic, appears from its increasing the motion of fluids, and from its extending itself to a considerable distance round excited bodies.

Do not all these experiments shew, that the electric matter is pure elementary fire, an original distinct principle, formed by the Creator himself? And not as some have apprehended, mechanically producible from other bodies?

And may it not be doubted whether this be not the only *elastic* body in the universe? Whether it be not the original spring, which communicates Elasticity to all other elastic bodies? To the air in particular: which is elastic no longer, when detached from electric fire, but commences *fixed* and unelastic; and seems to recover its Elasticity, only by recovering that ethereal fire which had been violently separated from it?

Scarce any phænomenon in nature has been esteemed more difficult to be accounted for, than those luminous appearances in the sky, termed Aurora Borealis, or Northern Lights. But these also may be rationally explained upon the principles of Electricity. We often see clouds at different heights, passing different ways, north and south at the same time. This manifestly proves different currents of air, one of them under the other.

Now

Now as the air between the tropics is rarefied by the sun, it rises: the denser air is pressed into its place. The air so raised moves north and south, and if it has no opportunity before, must descend in the polar regions. When this air with its vapours descends into contact with the vapours arising there, the electric fire which it brought begins to be communicated, and is seen in clear nights; being first visible where it is first in motion, namely in the most northern parts. But from thence the streams of light seem to shoot southerly, even to the zenith of northern countries.

To the same principle we may refer what some term St. Helmo's Fire, and the antient's Castor and Pollux, a thin, shining light, which is sometimes seen dancing on the decks or rigging of ships. A very remarkable account of this, is given by a late author. "In the night it became exceeding dark, and thundered and lightened dreadfully. We saw mean time on different parts of the ship, above thirty St. Helmo's Fires. One which was on the top of the vane of the main-mast, was more than a foot and a half in length. I ordered one of the sailors to take down the vane: the noise of the fire resembled that of fired wet gunpowder. Scarce had he lowered the vane, but the fire left it, and fixed on the top of the main-mast. After remaining there a considerable time, it went out by little and little.

"How immense a quantity of electric matter must have been at that time in the atmosphere surrounding the ship, to furnish more than thirty St. Helmo's Fires, (the same we see at the end of our conductors in electrifying) one of which was above a foot and a half long? The masts, yards,
and

and every part of the ship were then real conductors of the electric fire between the atmosphere and the sea, and by that means preserved the ship."

A person electrified acquires a flammific power, strong enough to light with one of his fingers, or with his cane, warm brandy. When the finger draws near, a crackling spark issues out, and sets it on fire.

The electric sparks of iron are of a silver white, those of brass, green, and those drawn from an egg, yellowish. This seems to prove, that the electric matter issuing from a body, is saturated with some parts peculiar to it.

Electricity quickens almost all sorts of motion, that of water in particular, which then glitters in the dark, the fire appearing intermingled with the water. It accelerates the motion of the human blood, quickening the pulse of fifteen or sixteen strokes in a minute. The blood that flows from the vein of one electrified, glitters, separates into small drops, and spouts out considerably farther than otherwise it would do.

It exceedingly hastens the vegetation of plants. Myrtle trees, which were electrified, budded much sooner than others of the same kind and bigness, in the same green-house. And seeds electrified daily have shot up and grown more in three or four days, than others of the same kind, and alike in all other circumstances, have done in eleven or twelve.

It cures abundance of diseases, even the most stubborn; particularly those of the nervous kind; many of them in a moment, by a single touch;
most

most, in a few days. So that this is not only one of the greatest curiosities in the world, but one of the noblest medicines that God ever gave to man.

Another phænomenon, which could never before be accounted for, is undoubtedly owing to this cause, the Sparkling observed on new Flannel, when it is rubbed in the dark. Very probably the acid steams of sulphur, which is burnt under the flannel, when it is bleached, unite with the oil where-with hair always abounds, and so form an animal sulphur, which upon any strong agitation of these hairs, will become luminous. This Sparkling is most observable in frosty weather, as Electricity is always strongest at that time. Flannel loses this property when it is washed, the lixivial salts of the soap, destroying the sulphureous acid, and likewise discharging its native acid. The wearing flannel, even without its being washed, will have the same effect: as the effluvia which go off in perspiration, dissolve the sulphur, and weaken the spring of the air.

A gentleman has lately made some curious experiments on the Electricity of hair. A lady had told him, that on combing her hair in frosty weather, in the dark, she had sometimes observed sparks of fire to issue from it. This made him think of attempting to collect the electrical fire from hair alone, without the assistance of any other electrical apparatus. To this end he desired a young lady to stand on a case of bees-wax, and to comb her sister's hair, who was sitting on a chair before her. Soon after she began to comb, the young lady on the wax was greatly astonished to

find her whole body electrified, darting out sparks of fire against every object that approached her. The hair was extremely electrified and affected an electrometer at a very great distance. He charged a metal conductor from it with great ease; and in the space of a few minutes collected as much fire from her hair as to kindle common spirits; and by means of a small phial, gave many smart shocks to all the company.

Electricity will probably soon be considered as the great vivifying principle of nature, by which she carries on most of her operations. It is a fifth element, distinct from, and of a superior nature to the other four, which only compose the corporeal parts of matter: but this subtle and active fluid is a kind of soul that pervades and quickens every particle of it. When an equal quantity of this is diffused through the air, and over the face of the earth, every thing continues calm and quiet; but if by any accident one part of matter has acquired a greater quantity than another, the most dreadful consequences often ensue before the equilibrium can be restored. Nature seems to fall into convulsions, and many of her works are destroyed: all the great phænomena are produced; thundering, lightening, earthquake, and whirlwinds; for there is now little doubt, that all these frequently depend on this sole cause. And again, if we look down from the sublime of nature to its minutiae, we shall still find the same power acting, though perhaps in less legible characters; for as the knowledge of its operations, is still in its infancy, they are generally misunderstood, or ascribed to some other cause. But doubtless in process of time these will be properly investigated;

investigated ; when men will wonder, how much they have been in the dark. It will then possibly be found, that what we call sensibility of nerves, and many of those diseases known only by name, are owing to the body's being possessed of too large or too small a quantity of this subtle and active fluid ; that very fluid perhaps, that is the vehicle of all our feelings ; and which has been so long searched for in vain in the nerves.

We all know that in damp and hazy weather, when it seems to be blunted, and absorbed by the humidity ; when its activity is lost, and little or none of it can be collected, our spirits are more languid, and our sensibility less acute. And in the fierce wind at Naples, when the air seems totally deprived of it, the whole system is unstrung, and the nerves seems to lose both their tension and elasticity, till the north or west wind awakens the activity of this animating power ; that soon restores the tone, and enlivens all nature, which seemed to droop and languish during its absence.

It is likewise well known, that there have been instances of the human body becoming electric without the mediation of any electric substance, and even emitting sparks of fire with a disagreeable sensation, and an extreme degree of nervous sensibility.

About eight or nine years ago, a lady of Switzerland was affected in this manner. She was uncommonly sensible of every change of weather, and had her electrical feeling strongest in a clear day, or during the passage of thunder clouds, when the air is known to be replete with that fluid. Her case was decided to be a nervous one.

Two gentlemen of Geneva had a short experience of the same complaint, though in a much superior degree. Professor Saussure and young Mr. Jalabert, when travelling over one of the high Alps, were caught amongst thunder clouds : and to their utter astonishment, found their bodies so full of electrical fire, that spontaneous flashes darted from their fingers with a crackling noise, and the same kind of sensation as when strongly electrified by art.

It seems pretty evident, that these feelings were owing to the bodies being possessed of two great a share of electric fire. This is an uncommon case ; but it is not at all improbable, that many of our invalids, particularly the hypochondriac, owe their disagreeable feelings to the opposite cause, or the bodies being possessed of too small a quantity of this fire ; for we find that a diminution of it in the air seldom fails to increase their uneasy sensations, and *vice versa*.

Perhaps it might be of service to these people to wear some electric substance next their skin, to defend the nerves and fibres from the damp, or new electric air. I would propose a waistcoat of the finest flannel, which should be kept perfectly clean and dry ; for the effluvia of the body in case of any violent perspiration, will soon destroy its electric quality : this should be covered by another of the same size of silk. The animal heat, and the friction that exercise must occasion betwixt these two substances, produce a powerful electricity ; and would form a kind of electric atmosphere around the body, that might possibly be one of the best preservatives, against the effect of damps.

As for our Swift lady I have little doubt that her complaints were owing in great part to her dress: and that a very small alteration almost in any part of it, would effectually have cured her.

A lady who has her head surrounded with wires, and her hair stuck full of metal pins, and who at the same time stands upon dry silk, is to all intents and purposes an electrical conductor, insulated, and prepared for collecting the fire from the atmosphere; and it is not at all surprizing that during thunder storms, or when the air is extremely replete with electrical matter, she should emit sparks, and exhibit other appearances of electricity. I imagine a very trifling change of dress, which from the constant versatility of their modes, may some day take place, would render this lady's disease altogether epidemical among the sex. Only let the soles of their shoes be made of an electric substance, and let the wires of their caps and pins of their hair, be somewhat lengthened and pointed outwards; and I think there is little doubt, that they will often find themselves in an electrified state: but indeed, if they only wear silk, or even worsted stockings, it may sometimes prove sufficient; for electrometers have been often insulated as perfectly by placing them on a piece of dry silk or flannel, as on glass.

How little do our ladies imagine, when they surround their heads with wire, the most powerful of all conductors; and at the same time, wear stockings, shoes, and gowns of silk, one of the most powerful repellants, that they prepare their bodies in the same manner, and according to the same principles as electricians prepare their conductors for attracting the fire of lightning! If they cannot be brought to relinquish their wire

caps, and their pins, might they not fall upon some such preservatives as those which of late years have been applied to objects of less consideration or consequence?

11. Next in subtilty to this ethereal fluid the Ether of Plants appears to be. It seems to be destitute of all gross air. For exhaust this ever so accurately, it remains unmoved, and does not emit any air-bubbles, which immediately arise in other liquors. A little of it poured on the hand, gives a sense of cold, equal to that caused by the contact of snow. Blow upon it once or twice, and your hand is dry. It causes an hissing when poured upon warm water, as if a piece of hot iron were thrown into it. Put a lump of sugar which has imbibed a little of it, into a vessel full of hot water, the sugar sinks; but the Ether rushing forth, excites a strong ebullition. If a spoonful of it be poured into a copper-pot full of boiling water; hold a candle near, and instantly there issues a great flash of lightning. Hence it appears, that this Ether, is both a very fluid water, and a most subtle fire; so that if kindled in a thousand times the quantity of cold water, it burns inextinguishably.

It does not manifest the least oiliness to the touch; yet is it the true, natural dissolvent of all fat oils and gums whatever.

It has a wonderful harmony with gold, even greater than that which is between gold and Aqua Regia. Dissolve a piece of gold in Aqua Regia: on the solution cold pour half an ounce of Ether. Shake the glass, and all the gold will pass into this, and the Aqua Regia robbed of all its gold, will deposit a white powder, which soon turning
green,

green, is the copper wherewith the gold was adulterated. Ether then is the most noble and efficacious instrument in chymistry, and pharmacy, inasmuch as essences and essential oils are extracted by it immediately, without the mediation of fire, from woods, barks, roots, herbs, flowers, seeds, and the various parts of animals.

For instance, take mint, sage, cinnamon, or all together, cut and bottle them; pour on them a spoonful or two of Ether, and after it has stood an hour in a cool place, fill up the bottle with cold water, and presently you will see the essential oil swimming upon the water. In like manner, though not so immediately, it extracts the purest gold from any of the baser minerals. And the gold thus extracted, is better and sooner purified by this one operation, than by fusion with antimony. It is the lightest of all liquors. Seven ounces of this fill a phial, which contains twenty even of oil of vitriol. And it is the purest flame, leaving neither soot nor ashes after its deflagration.

12. Wind is a current of air. Wherever the air is rarefied or condensed beyond its natural degree, a wind must necessarily ensue, till the equilibrium be restored: the condensed air immediately expanding itself toward that which was rarefied. The causes of this condensation or rarefaction, are heat, cold, and a thousand things beside.

The Heat in the West India islands would be intolerable, if the winds rising as the sun gathers strength, did not blow from the sea, so as to temper the heat even of the noon-day sun. On the other

hand, as the night advances, a breeze arises from the land, and blows as from its center towards the sea, to all points of the compass at once.

At Aleppo the coldest winds in the winter are those which blow from N. W. to E. the nearer the east the colder. But from May 1, to the end of September, the winds blowing from the same points, bring with them a heat which one would imagine came out of an oven, and which, when it blows hard will affect metals within the houses, as if they had been exposed to the rays of the sun. Yet it is remarkable, that water kept in jars is much cooler at this time, than when a cool westerly wind blows.

But what degree of heat can an human body bear? A gentleman, desirous to ascertain this, heated several rooms by means of flues, from 100 degrees of Fahrenheit's Thermometer to 210. He found he could bear the heat of 210 without suffering much, and could breathe freely, when his pulse beat 165 beats in a minute. Even then placing the ball of the thermometer under his tongue, the glass sunk to 100, and the flesh of his body felt as cold as a corpse. Yet his watch chain was so hot, he could scarce touch it.

Hence he inferred that a human body has, to a certain degree a power of *destroying heat*, as well as a power of *generating heat*, as circumstances may require. This results from the principle of life itself, and accordingly is not found in any inanimate body.

A wind of a very peculiar kind, passed over the city of Rome, on the night of the 11th of June, 1749. There first appeared a very black long and lofty cloud, which emitted flames on all sides. It moved

moved along with a surprizing swiftness, within three or four feet of the ground. It first gathered in the neighbouring sea, came from Ostia to Rome, entered the city between the gates of St. Paul and St. Sebestian, and crossing in a strait line, went out at the north angle of a large square, between the Porta Pia and that of St. Lawrence. It stripped off the roofs of houses, blew down the chimneys, broke doors and windows, forced up the floors, and unpaved the rooms. It tore up the vines, and overthrew the trees in its way, and where its action was most violent, the very rafters of the houses were broke, yea, and hurled against houses at a considerable distance. The loftiest buildings felt its fury the most: those of one story were little damaged. It was traced to some distance without the city, then it died away.

The motions of all these hurricanes is circular, and they carry up into the air, tiles, stones, and whatever comes in their way, and throw them violently to a considerable distance. To this may be owing some of those surprizing showers which are recorded in history. A whirlwind, for instance, passes over a place where wool is spread to dry. It takes it up, and scatters it in small locks, at a considerable distance. Here is the appearance of a shower of wool. If it sweeps along a mineral rivulet, of which there are many among the mountains of Italy, it carries innumerable metallic particles away, and sprinkles them on some distant town or fields. Here is what they call a shower of iron.

Hurricanes are foreseen at the Antibes by a calm, and then a shifting of breezes from all quarters; the sun-sets blood red, small clouds fly

to and fro with great rapidity. Sea-birds quit the air and seek the shore. Soon after a north breeze springs up, which comes to the north-east. Afterwards it is south and south-east, and the air is darkened by a black cloud.

In the last hurricane, the wind stood at north-east, and blew with such violence, that the largest trees were torn up by the roots, their trunks broken to pieces, and not a leaf left on those other trees, which yielded to the fury of the winds. The houses were thrown down, and the tops of the sugar-mills, which could not well be thrown down, were crushed in pieces. At the end of an hurricane we see lightning, and hear the noise of thunder. Then the wind softens gradually, till all becomes quiet.

When there was a violent hurricane at Guadeloupe, there appeared upon the island, a thick black cloud, which seemed on fire, and gravitating toward the earth. It occupied a space of five or six leagues in front. Above it the air was almost clear, there appearing only a kind of mist. The whole force of an hurricane is lodged in the very body of a cloud, containing wind, rain, lightning, and thunder: where the air is compressed, and rolling upon itself, causes the storms, which nothing can resist. Nor does the hurricane end, till the cloud bursts, and the thunder and lightning come on.

One species of Hurricanes is that which is termed a Water-Spout. These are seen to descend from a cloud as a pillar, having two motions, one round their own axis, the other progressive

gressive in a strait direction. Such a spout is a gyration of clouds, by contrary winds meeting in the centre, and there (where the condensation and gravitation are greatest) sinking down into a great tube, like a screw. In its working and whirling, it sucks and raises the water, in the same manner as the spiral screw does. One of these sometimes appears on the land. On June 21, some years since, the clouds near Hatfield in Yorkshire were observed to be much agitated and driven together. They soon became very black, and were hurried round: hence proceeded a whirling noise like that of a mill. Soon after there issued a long tube from the centre of the congregated clouds, having a screw-like motion, by which means the water wherever it came was raised up. In August following, the wind blowing at the same time out of several quarters, created a great whirling among the clouds, the centre of which every now and then sunk down, like a long, black pipe, wherein was distinctly seen a motion like that of a screw, continually drawing and screwing up, as it were, whatever it touched. Groves and trees bent under it circularly, like wands. Some of the branches it tore off. It is commonly supposed, that the water at sea rises in a column, before the tube touches it. But this is a mistake. The tube often touches the surface of the sea, before the water rises at all.

But Water-Spouts happen several ways. Sometimes the water is seen to boil, and raise itself for a considerable space about a foot from the sea, before the tube touches it. Above this there appears as it were a thick and black smoke, in the midst of which is a sort of pipe, resembling a tunnel, reaching up to the clouds. At other times

these tunnels come from the clouds, and suck up the water with great violence. Sometimes these discharge themselves into the sea, to the unavoidable destruction of such ships as are in their way: sometimes on the shore, beating down all they meet with, and raising the sand and stones to a prodigious height.

A very distinct account of this kind was given some time since by an eye witness.

“ We were on the coast of Barbary, when three Water-Spouts came down: one of them bigger than three masts, the other two scarce half as big: all of them were black, as the cloud from which they fell; all smooth, and smaller at the lower end. Sometimes one became smaller, and then larger again; sometimes it disappeared, and quickly fell down again.

“ There was always a great boiling and flying up of the water, like the appearance of a smoking chimney in a calm day. Sometimes it stood as a pillar some yards above the sea, and then spread itself and scattered like smok. One spout came down to the very middle of this pillar, and joined with it. Afterwards it pointed to the pillar at some distance, first in a perpendicular, and then in an oblique line.

“ It was hard to say, whether this Spout fell first from the cloud, or the pillar rose first from the sea, both appearing opposite to each other, as in the twinkling of an eye. But in another place the water rose up to a great height, without any Spout pointing to it. Only here, the water did not rise like a pillar, but flew scatteringly, and advanced as a moving bush upon the surface of the sea. This proves, that the rising
of

of the water may begin, before the Spout from the cloud appears.

“ All these Spouts, but especially the great one toward the end, began to appear like a hollow canal, along the middle of which one might distinctly perceive the sea water fly up very swiftly : soon after the spout broke in the middle, and disappeared by little and little ; the boiling up, yea, the pillar of sea-water continuing a considerable time after.”

There is something very uncommon in the Fetter, a lake which parts East and West Gothland. It is about eighty miles long and eighteen broad. Its water is very clear, and in some places so deep, as not to be sounded by a line of 300 fathom. It is often disturbed by storms, which sometimes begin so suddenly, that the surface of the water is agitated, before the least breath of wind is perceived. And it is not uncommon for boats in one part of the lake to be tossed by a violent storm, while others at a small distance, are in a perfect calm. Immediately before a storm, while the sky is clear, a noise is perceived in the Lake like thunder. Of this the inhabitants of Visingore, an island in the middle of the Lake, are more sensible than any others. For from that part of the island, whence the wind will blow, they hear a noise like the firing of cannon. Whenever this is heard in the east, they expect hail and rain to follow. Undoubtedly all these storms are owing to subterraneous winds. To these likewise we may attribute the sudden cracking of the ice upon the Lake in the spring. This is one minute strong enough to bear horses and sledges, and the next broken in pieces. A strange noise underneath,
which

which precedes the breach, warns travellers to make the best of their way. But those who happen to be at a great distance from land are swallowed up, unless they can float upon shoals of ice, till they meet with relief. The violent *under-currents* observed in this lake, are also very surprizing. These directly opposing the winds, give the fishermen a great deal of trouble. From these, as well as from its unfathomable depths, it is supposed to have a communication under ground with another lake, called Venner, about forty miles to the westward.

13. It remains only to add a few Reflections, on some of the preceding heads.

How useful is the atmosphere to the life, the health, the comfort, and the business of the whole globe? It is the air, † by which all animals live:
not

† As the air is of absolute necessity to animal life, so it is necessary it should be of a due consistence, not foul, for that suffocates; not too thin; for that suffices not.

In the diving-bell, after some time of stay under water, they are forced to come up and take in fresh air. But Cornelius Drebell contrived not only a vessel to be rowed under water, but also a liquor to be carried therein, that would supply the want of fresh air. The vessel was made for King James the First. It carried twelve rowers besides the passengers. It was tried in the Thames. A person who was therein told it one who related it to Mr. Boyle. As to the liquor, Mr. Boyle discovered by a physician, who married Drebell's daughter, that from time to time, when the air in the submarine boat was so clogged by the breath of the company, as to be unfit for respiration, by unstopping a vessel full of this, he speedily restored it, so that they breathed again without difficulty.

not only the inhabitants of the earth, but the of waters too. Without it most animals live scarce half a minute, and none of them, many days.

And not only animals, but even trees and plants owe their life and vegetation to this useful element : as is manifest from their glory and verdure in a free air, and their paleness and sickness, when excluded from it.

Thus necessary is the air to the life of animals. And it is no less so, to the conveyance of many of them. All the winged tribes owe their flight and buoyancy to it. And even the inhabitants of the waters, cannot easily ascend or descend in their own element without it.

It would be endless to specify the uses of the air in the operations of nature. To touch only on one or two instances. How admirable is that property of it, the conserving animated bodies, whether animal or vegetable, while it dissolves all other bodies; by which means many things which would prove nuisances to the world, are put out of the way, and reduced to their first principles. Even chrystal-glasses, especially if not used, it will in time reduce to powder. And thus divers minerals, stones, fossil-shells, trees, which have lain under ground for many ages, and
so

And as too gross, so too thin an air, is unfit for respiration. Hence the difficulty of breathing, (as all travellers relate) upon the top of high mountains. But the cause of this difficulty is not the thinness only, but the too great lightness thereof, which renders it unable to be a counterbalance to the heart, and all the muscles ministering to respiration.

so secure from corruption, when in the open air, have quickly mouldered away.

Another admirable use of our atmosphere is, its ministring to the enlightning the earth, by reflecting to us the light of the sun, § and refracting his beams to our eye, before he surmounts our horizon, by which means the day is protracted throughout the whole globe, and the long and dismal nights are shortened in the frigid zones. Yea, the sun rises in appearance, when he is indeed many degrees below the horizon.

Let us a little more attentively consider the light which whitens the sky before the sun rises. There is something surprising in this. We see the light only by the rays which flow to our eyes. Now the Sun being as yet beneath the earth, cannot project any of his rays directly to us. And the rays which dart on the extremities of the land that terminates our sight, proceed farther into the heavens, unless they meet with any body, which reflects them back to us. Is there any particular body in nature designed to do us this service? There is, namely the atmosphere, which is framed over our heads in such a manner, that notwithstanding its extensive mass, it suffers us to see the stars, at an immense distance from us; and notwithstanding its transparency, bends and gathers

§ To this is owing that whiteness which is in the air in the day-time, caused by the rays of light, striking on the particles of the atmosphere, as well as upon the clouds above, and the other objects beneath on the earth. To the same cause we owe the twilight, namely to the sunbeams touching the uppermost parts of the atmosphere, which they do, when the sun is eighteen degrees below the horizon.

thers for us numberless rays, of which we should otherwise be quite deprived.

Any ray that falls perpendicularly on the atmosphere, enters it without any obstacle, and descends through it to the earth in the same right line. But those which fall obliquely upon it, are admitted into, or repelled from it, according to the situation of the luminous body. If this be more than eighteen degrees below the horizon, all its rays are scattered abroad. If less, the rays enter the atmosphere, and are refracted to our sight. This is the true cause of the twilight, and indeed of the continuance and principal beauty of the day, even when the sun is in its highest elevation. The earth which receives his rays, reflects them into the atmosphere, which once more returns the greater part of them. Thus it preserves to us that splendor which is the beauty of nature, and that heat which is the soul of it. For it collects numberless rays, the greater or smaller union whereof, is the measure of heat and cold. Thus it becomes to us a mantle of the finest texture, redoubling the heat, yet not pressing us by its weight.

The Atmosphere at the same time causes and maintains round us, that light which lays our whole habitation before our eyes. In order to clear this, suppose the atmosphere were destroyed,

1. The rising of the sun would not be preceded by any twilight, but the most intense darkness would surround us, till the moment of his rising.
2. In that instant he would break out in his full brightness, and so continue till his setting: and that moment it would be pitch dark.
3. In the day

day his light would resemble a clear fire, which we see by night in the midst of a spacious field. We should see what was near us, but nothing else: the distant lands would not be perceived, and the night would still continue, notwithstanding the sun. For instead of the white tint of day, which displays all nature by brightening the azure of the heavens, and colouring all the horizon, we should see nothing but an abyss of darkness, there being nothing to reflect the solar rays. The stars indeed would be seen at noon-day: but then those luminous bodies, which now appear to be placed in a delightful azure, would seem fastened on a dismal, mourning carpet.

“ But how does that fine azure depend on the atmosphere ?” This will plainly appear, if it be considered, what a quantity of rarefied water is suspended from the top of the atmosphere to the bottom. And there is never a greater quantity suspended there, than in the fine days, when no clouds are to be seen. It is these rarefied waters, that intercept and reflect to us, the rays reflected from the earth. And this prodigious mass of waters, being a simple and uniform body, the colour of it is simple, and always the same.

“ But are these azure skies, which we confound with the starry heaven, nothing more than a little air and water ? And what we took for the heaven, only a cover wrapt close round the earth ?” So it is. And this is a new wonder, and a new proof of our Creator’s wisdom ! A few small bubbles of air and water are indeed in themselves things very insignificant ; but that hand which has with so much art and caution placed them

them over our heads, has done it merely, that his sun and stars might not be rendered useless to us. He embellishes whatever he pleases; and these drops of water and air become in his hands an inexhaustible source of glory. He draws from them those twilights, which so usefully prepare our eyes for the receiving a stronger light. He fetches out of them the brightness of the dawn. From them he produces the splendor of the day. He makes them contribute to the increase and preservation of that heat which nourishes every thing breathing. Of them he makes a brilliant arch, which enchants the sight of man, and becomes the ceiling of his habitation.

I shall only add the excellent use of the atmosphere, in respect of two of its meteors, the winds, and the clouds and rain.

The winds|| are of such absolute necessity to the wholesomeness of the atmosphere, that all the world would be poisoned without those agitations. We find how putrid and unfit for respiration, a confined, stagnating air is. And if the whole mass of air and vapours were always at rest, instead

|| The most universal and constant alterations of the balance of the atmosphere are from heat and cold. This is manifest in the general Trade-Winds, blowing all the year between the tropics from east to west: the cause whereof is undoubtedly by the sun's daily progress round that part of the globe, by his heat rarefying one part of the air, while the cooler and heavier air behind presses after.

In Thunder-Storms there are often two currents of air, the under-current contrary to the upper. Hence the wind near the earth blows one way, and the clouds more above the other way.

stead of refreshing, it would suffocate all the world. But the motion it receives from the gales and storms, keeps it pure, and healthy still.

Without these gales to fan us also, in the heat of summer, even in our temperate climate, men would hardly be able to go through their daily labour, without endangering their health.† These are perpetual in the torrid zone, and make what the antients imagined, to be not habitable to any but wild beasts, an healthful and pleasant habitation.

Of what use likewise are the winds, to transport men to the distant regions of the world? Particularly, the general and coasting trade-winds, the sea and the land breezes; the one serving to carry the mariners in long voyages from east to west; the other, to waft him to particular places: the one serving to carry him into his harbour, the other to bring him out. Sea-breezes commonly rise in the morning, about nine o'clock. They first approach the shore gently, as if they were afraid to come near it. The breeze comes in a fine, small, black curl upon the water, whereas all the sea between it and the shore, is as smooth and even as glass. In half an hour after it reaches the shore, it fans pretty briskly, and so increases gradually till twelve o'clock: then it is commonly the strongest. It lasts so till two or three.

† July 8, 1707, called for some time after, The Hot Tuesday, was so excessively hot and suffocating, by reason of there being no wind at all, that divers persons died in their harvest-work. An healthy, lusty, young man, near Upminster in particular, was killed on the spot by the heat, and several travellers on the road dropt down and died.

three. At three it begins to die away, till about five it is lulled asleep. As the sea-breezes blow in the day, and rest in the night; the land-breezes blow in the night, and rest in the day. They spring up between six and twelve at night, and last till six, eight, or nine in the morning.

The clouds and rain are no less useful meteors than the winds, as is manifest in the refreshing shade which the clouds afford, and the fertile dews and showers, which they pour down on the trees and plants, which would languish and die with perpetual drought, but are hereby made verdant and flourishing; so that as the Psalmist saith, *The little hills rejoice on every side, and the valleys shout for joy, and sing.*

A farther improvement of these remarks I subjoin in the words of Mr. Hervey.

“ If we turn our thoughts to the *atmosphere*, we find a most curious and exquisite apparatus of *air*. This is a source of innumerable advantages; all which are fetched from the very jaws of ruin. To explain this. The *pressure* of the air on a person of a moderate size is equal to the weight of *twenty thousand* pounds. Tremendous consideration! Should an house fall upon us with half that force, it would break every bone of our bodies. Yet so admirably has the Divine Wisdom contrived the air, and so nicely counterpoised its dreadful power, that we suffer no manner of inconvenience; we even *enjoy* the load. Instead of being as a mountain on our loins, it is as wings to our feet, or sinews to our limbs. Is not this *common* ordination of Providence, somewhat like the
miracle

miracle of the burning bush? Well may we say unto God, O how terrible, yet how beneficent, art thou in thy works!

“ The air, though too weak to support *our* flight is a thoroughfare for innumerable wings. Here the whole commonwealth of birds expatiate, beyond the reach of their adversaries. Were they to run upon the earth, they would be in ten thousand dangers, without strength to resist, or speed to escape them : whereas by mounting the skies, they are secure from peril, they *scorn the horse and his rider*. Some of them perching on the boughs, or soaring aloft, entertain us with their notes. Many of them yield us wholesome and agreeable food, and yet give us no trouble, put us to no expence, but till the time we want them, are wholly out of the way.

“ The air is charged also with several offices, absolutely needful for mankind. In our lungs it *ventilates* the blood, qualifies its warmth, promotes the animal secretions. We might live even months, without the light of the sun, yea, or the glimmering of a star. Whereas, if we are deprived but a few minutes of this, we sicken, we faint, we die. The same *universal nurse* has a considerable share in cherishing the several tribes of plants. It transfuses vegetable vigour into the trunk of an oak, and a blooming gaiety into the leaves of a rose.

“ The air likewise conveys to our nostrils the extremely subtle Effluvia which exale from odoriferous bodies: particles so small, that they elude the most careful hand. But this receives
and

and transmits the invisible vagrants, without losing even a single atom; entertaining us with the delightful sensations that arise from the fragrance of flowers, and admonishing us to withdraw from an unwholesome situation, to beware of pernicious food.

“ The air by its undulating motion conducts to our ear all the diversities of *Sound*. While danger is at a considerable distance, this advertises us of its approach; and with a clamorous but kind importunity, urges us to provide for our safety.

“ The air wafts to our sense all the modulations of music, and the more agreeable entertainments of conversation. It distributes every musical variation with the utmost exactness, and delivers the message of the Speaker with the most punctual fidelity: whereas, without this internuntio, all would be fullen and unmeaning silence. We should neither be charmed by the harmonious, nor improved by the articulate accents.

“ How gentle are the breezes of the air when unconfined! but when collected, they act with such immense force, as is sufficient to whirl round the hughest wheels, though clogged with the most incumbering loads. They make the ponderous millstones move as swiftly as the dancers heel; and the massy beams play as nimbly as the musician's fingers.

“ In the higher regions there is an endless succession of Clouds, fed by evaporations from the ocean. The clouds are themselves a kind of ocean, suspended in the air. They travel in detached

tached parties, over all the terrestrial globe. They fructify by proper communications of moisture, the spacious pastures of the wealthy, and gladden with no less liberal showers the cottager's little spot. Nay, they *satisfy the desolate and waste ground, and cause the bud of the tender herb to spring forth*: that the natives of the lonely desert, the herds which know no master's stall, may nevertheless experience the care of an all-supporting parent.

" How wonderful! That *pendant Lakes* should be diffused, fluid mountains heaped over our heads, and both sustained in the thinnest part of the atmosphere. How surprising is the expedient which without vessels of stone or brass, keeps such loads of water in a buoyant state? Job considered this with holy admiration. *Dost thou know the balancings of the clouds?* How such ponderous bodies are made to hang in even poise, and hover like the lightest down? *He bindeth up the waters in his thick cloud: and the cloud, though nothing is more loose and fluid, becomes by his order tenacious, as casks of iron, is not rent under all the weight.*

" When the sluices are opened and the waters descend, one would think they should pour down in torrents. Whereas instead of this, which would be infinitely pernicious, they coalesce into globules, and are dispensed in gentle *showers*. They spread themselves as if strained through the orifices of the finest watering-pot, and form those *small drops of rain* which the clouds *distil upon man abundantly*. Thus instead of drowning the earth, and sweeping away its fruits, they cherish universal nature, and (like their great master) distribute their stores, to
men,

animals, vegetables, *as they are able to bear them.*

“ But beside waters, here are cantoned various parties of winds, mild or fierce, gentle or boisterous, furnished with breezy wings, to *fan* the glowing firmament, or else fitted to act as an universal *besom*, and by sweeping the chambers of the atmosphere to cleanse the fine aëreal fluid. Without this wholesome agency of the winds, the air would stagnate and become putrid: so that all the great cities in the world, instead of being seats of elegance, would degenerate into sinks of corruption.

“ At sea, the winds swell the mariner’s sails, and speed his course along the watery way. By land they perform the office of an immense *seeds-man*, scattering abroad the seeds of numberless plants, which, though the support of many animals, are too small for the management, or too mean for the attention of man.

“ Here are lightnings stationed, in act to spring whenever their piercing flash is necessary, either to destroy the *sulphureous* vapours, or dislodge any other *noxious* matter, which might prejudice the delicate temperature of the Ether, and obscure its more than chryselline transparency.

“ Above all is situate a radiant and majestic orb, which enlightens and cheers the inhabitants of the earth: while the air, by a singular address, amplifies its usefulness. Its *reflecting* power augments that heat, which is the life of nature: its *refracting* powers prolongs that splendor, which is the beauty of the creation.

“ I say, *augments the heat*. For the air is a *cover* which, without oppressing us with any perceivable weight, confines, reflects, and thereby increases the vivifying heat of the sun. The air increases this, much in the same manner as our cloaths give additional heat to our body : whereas when it is less in quantity, when it is attenuated, the solar heat is very sensibly diminished. Travellers on the lofty mountains of America, sometimes experience this to their cost. Though the clime at the foot of those vast mountains, is extremely hot and sultry, yet at the top the cold is so excessive, as often to freeze both the horse and rider to death. We have therefore great reason to praise God, for placing us in the commodious concavity, the cherishing wings of an atmosphere.

“ The emanations of Light, though formed of inactive matter, yet (astounding power of divine wisdom !) are refined almost to the subtilty of spirit, and are scarce inferior even to thought in *speed*. By which means they spread with almost instantaneous swiftness, through an whole hemisphere : and though they fill whatever they pervade, yet they straiten no place, embarrass no one, incumber nothing.

“ Every where indeed, and in every element we may discern the footsteps of the Creator's wisdom. The spacious canopy over our heads is painted with blue ; and the ample carpet under our feet is tinged with green. These colours, by their soft and chearing qualities, yield a perpetual refreshment to the eye. Whereas had the face of nature glistened with white, or glowed with scarlet, such dazzling hues, instead of chearing, would have fatigued the sight. Besides, as the several brighter
colours

colours are interspersed, and form the pictures in this magnificent piece, the green and the blue make an admirable *ground*, which shews them all to the utmost advantage.

“ Had the air been much *grosser*, it would have dimmed the rays of the sun and darkened the day. Our lungs would have been clogged in their vital function, and men drowned or suffocated therein. Were it much more *subtle*, birds would not be able to wing their way through the firmament : neither could the clouds be sustained, in so thin an atmosphere. It would elude likewise the organs of respiration : we should gasp for breath with as much difficulty, and as little success as fishes do, when out of their native element.

“ The ground also is wrought into the most proper temperature. Was it of a firmer consistence it would be impenetrable to the plough, and unmanageable by the spade. Was it of a more *loose* composition, it would be incapable of supporting its own furniture. The light mould would be swept away by whirling winds, or soaked into sloughs by the descending rains. Again, because every place suits not every plant, but that which nourishes one, destroys another : the qualities of the earth are so abundantly diversified as to accommodate every species. We have a variety of intermediate soils, from the *loose* sand to the *stiff* clay : from the rough projection of the craggy rock, to the soft bed of the smooth paterre.

“ The Sea carries equal evidences of a most wise and gracious ordination. Was it *larger*, we should have wanted land for pasturage and husbandry. We should not have had room for mines and

forests, our subterranean warehouses and æreal timber-yards. Was it *smaller*, it could not recruit the sky with a proper quantity of exhalations: nor supply the earth with the necessary quota of fructifying showers.

“ May we not discover as exquisite strokes of wisdom in each individual object? All that shines in the heavens, and all that smiles on the earth, speak their infinitely wise Creator. Need we launch into the praise of the vallies cloathed with grass, or of the fields replenished with corn? Even the ragged rocks, which frown over the flood, the caverned quarries which yawn amidst the land, together with the shapeless and enormous mountains, which seem to load the ground, and encumber the skies; even these contribute to increase the general pleasure, and augment the general usefulness. They add new charms to the wide level of our plains, and shelter, like a screen the warm lap of our vales.

“ Who is not charmed with the delicious fruits of summer and autumn? But were all our trees and shrubs to produce such fruits, what would become of the birds? How small a part would voracious man resign to their enjoyment? To provide therefore for each vagrant of the air, as well as for the sovereign of a nation, there is in all places a large growth of shrubs, annually covered with coarse and hardy berries: so coarse in their taste, that they are unworthy of the acceptance of man: so hardy in their make, that they endure the utmost severity of the weather, and furnish the feathered tribes with a standing repast amidst all the desolations of winter.

“ The

" The fir, the beech, the elm, are stately decorations of our rural seats. But if there were no entangling thickets, no prickly thorns, where would the farmer procure fences? How could he secure his vegetable wealth, from the flocks and the herds? Those roving plunderers, which submit to no laws, but those of the coercive kind.

" We spare no toil, to have useful herbs and plants in our gardens, and upon our tables. But there are innumerable herbs, which pass under the contemptable character of Weeds, and yet are full as desirable to other classes of creatures, as these are to mankind. Yet who will be at the pains to plant, to water, to cultivate, such despicable productions? Man would rather *extirpate* than propagate, these incumbrances of his land. Therefore Providence vouchsafes to be their gardener, and has wrought off their seeds with such a lightness, that they are transported to and fro, by the mere undulations of the air. Or, if too heavy, to be wafted by the breeze, they are fastened to wings of down : or else inclosed in a springy case, which forcibly bursting, shoots them out on every side. By some such means, the re-producing principle of every one is disseminated, the universal granary filled, and the universal board furnished. The buzzing insect and the creeping worm, have each his bill of fare. Each enjoys a never-failing treat, equivalent to our greatest delicacies.

" If Grass was scarce as the Guernsey-lilly, and as difficultly raised as the Tuberosa, how certainly, and how speedily, must many millions of animals perish by famine? But as all the cattle owe

their chief subsistence to this, by a singular wisdom in the divine æconomy, *it waiteth not*, like the corn field, and the garden-bed, *for* the annual labours of *Man*. When once sown, though ever so frequently crompt, it revives with the returning season. With a kind of perennial verdure, it covers our meadows, diffuses itself over the plains, springs up in every glade of the forest, and spreads a side-board in the most sequestered nook.

“ Such is the care of a wise and condescending Providence, even over these lowest formations of nature!”

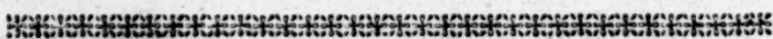




P A R T the F I F T H.

Of the System of the WORLD;
Of the HEAVENLY BODIES;

AND OF THE
Properties & Causes of NATURAL BODIES.



C H A P. I.

Of the System of the WORLD.

- | | |
|---|--|
| 1. <i>The General Phaenomena of the Sun and Moon.</i> | 5. <i>The Ptolemaic System.</i> |
| 2. <i>Of Mercury and Venus.</i> | 6. <i>The Copernican.</i> |
| 3. <i>Of the other Planets.</i> | 7. <i>The System of Tycho Brahe.</i> |
| 4. <i>Of the Comets and fixed Stars.</i> | 8. <i>The Hutchinsonian System.</i> |
| | 9. <i>Advantages from the rotation of the Earth.</i> |

1. **H**AVING considered the earth, with the bodies that are therein, let us now look up to those that surround it. The world is
M 4 a congeries

a congeries of innumerable bodies, many of which are supposed to equal or exceed the size of the earth: yet by reason of their distance, most of them are invisible to the naked eye.

The nearest to us is the Moon, which moves round the earth in something more than twenty-eight days from west to east. The Sun likewise seems to move from east to west, and shines successively on all parts of the globe. It appears also to us to move every year obliquely from west to east, coming twenty-three degrees and a half to the north, and then going just as far to the south.

2. Some of the Stars keep always the same distance, with respect to each other, and are termed fixed. Others are continually changing their situation, whence they are termed Planets. Two of these, Mercury and Venus, are frequently between the earth and the Sun: of which the former being generally hid by the rays of the sun, is seldom visible: but Venus, commonly called the Evening Star, is very conspicuous. The earth is never between them and the sun. They are sometimes between us and him. Sometimes the sun is interposed between us and them.

3. The upper planets are Mars, Jupiter, and Saturn. The sun is sometimes between these and the earth. But none of them is ever interposed between the earth and the sun. Mars has different appearances, like the moon, as it is differently situated, with regard to the sun: whereas Jupiter and Saturn always appear with the same aspect, and have smaller planets revolving round them.

All

All these revolve round the sun, in their several stated periods.

4. Beside these, there is another kind of stars called Comets, vulgarly Blazing Stars. These do not revolve round the sun, in so regular orbits as the planets. The *fixed Stars* are above these: about 2200 are visible to the naked eye. These have a vivid light, and always appear with the same face towards us: they seem to have a two-fold motion, a slow one from east to west in a year, and a swift one round the earth with all the other stars in four and twenty hours. But there are some of them which never set, namely those near the north or south pole.

5. To explain these phænomena of the heavenly Bodies, various systems have been invented. The Ptolemaic supposes the earth to be fixed in the center of the universe, round which all the heavenly Bodies move, each affixed to a solid sphere which moves with that: first the Moon, then Mercury, thirdly, Venus, next the Sun, fifthly Mars, then Jupiter, seventhly, Saturn. In the eighth place is the Firmament or sphere of Fixed Stars: then the Chrystalline Heaven, and last of all the Primum Mobile, which is supposed to move from east to west in twenty-four hours, whirling all the other spheres with it. But this system being in some respects obviously false, in others utterly improbable, and likewise insufficient to account for many phænomena, is now universally exploded.

6. In the room of this, the Copernican system is now generally received, which supposes the
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sun

sun to be fixed in the center, without any other motion, than that round his own axis. Next him is Mercury, then Venus, thirdly the Earth, (round which the Moon revolves) above the earth. Mars, then Jupiter, and Saturn, with their attendant Moons. This system is extremely simple and natural, and easily accounts for most phænomena. As to the objection, that it is contrary to the testimony of our senses, it is easily answered. They who are in a ship seem to see the shore and the land moving along, although it is really the ship that moves. Yet let it move ever so swiftly, it displaces nothing, provided it move smoothly. So neither does the motion of the earth displace any thing on its surface, because it is equable and regular.

Not that Copernicus was the inventor of this system. It was in great part known long ago. Pythagoras taught, " that the earth was carried about the sun among the stars, and by turning round its axis, caused day and night." Yet by degrees it sunk into oblivion, till it was revived by Cardinal Cusa. However, the Ptolemaic system still prevailed, till Nicholas Copernicus, a canon of Thorn, in Polish Prussia, born in the year 1473, had resolution to examine it thoroughly, and learning enough to explain and defend it. Some of the reasons on which this system is founded are, 1. This is most simple and agreeable to the whole tenure of nature: for by the two motions of the earth all the phænomena of the heavens are resolved, which on any of the other hypothesis are utterly inexplicable. 2. It is more rational to suppose the earth moves round the sun, than that the huge bodies of the planets and of the sun itself, and the immense firmament of stars, should all move round the inconsiderable body of earth every four and
twenty

twenty hours. 3. The earth's moving round the sun is agreeable to that general harmony and universal law, which all other moving bodies of the system observe, namely, that the squares of the periodical times are as the cubes of the distances. But if the sun move round the earth, that law is destroyed, and the general order and symmetry of nature interrupted; because according to that law the sun would be so far from revolving about the earth in 365 days, that it would require no less than 5196 years, to finish one revolution. 4. The sun is the fountain of light and heat, which it darts through the whole system, and therefore it ought to be placed, as the heart in the center, that so all the planets may at all times have them, in an uniform and equal manner. 5. If the sun be placed in the center of the system, we have then the rational hypothesis of the planets being all moved about the sun, by the universal law of gravity: and every thing will answer to that law; but otherwise we are wholly in the dark. 6. But we need not rely upon conjectures. We have demonstrative proofs, that the sun possesses the center, and that the planets move round it, in the order above mentioned. For example. Mercury and Venus are ever observed to have two conjunctions with the sun, but no opposition, which could not happen unless the orbits of those planets lay within the orbit of the earth. And in the same manner it may be demonstrated, that the orbits of Mars, Jupiter, and Saturn, lie without the orbit of the earth.

7. After Copernicus came Tycho Brahe, a noble Dane, who endeavoured to compound a system of the Ptolemaic and Copernician put together.

But it was quickly found by all unprejudiced judges, to be so intricate and perplexed, that it had not many assertors even while he lived, and is now well nigh sunk into oblivion.

8. Mr. Hutchinson (not the professor of Glasgow, but a private English Gentleman) supposes the constituent parts of heaven to be, 1. The *darkness*, or dark air, which is no other than the fine ether in a state of stagnation: 2. The *spirit*, or the air in a sensible motion: 3. The *light*, the finest part of the heavens, the pure ether in motion: 4. The *luminaries* and their *fluxes*. Understand by the *luminaries*, the *bodies* of the sun, moon, and stars: by their *fluxes*, the flow of light that comes from each of them. Revelation constantly distinguishes these. Therefore it is very improper for us to confound them together. Indeed every one knows, that though the bodies of the sun, moon, and stars, take up but a small part of the heavens, yet the fluxes of light from them diffuse themselves throughout all nature.

The springing forth of the solar light causes the morning; its going off, the evening. Its being intercepted by the body of the earth causes *night*; its shining causes *day*. It acts in a mechanical way, and is part of the great machine of nature. It is in continual motion to and from the body of the sun: going out from the center to the circumference of the heavens, and returning to the center again. The solar light, along with the spirit, which continually attends it, is the cause of the regular returns of morning and evening, summer and winter. The spirit and light are properly the agent, and the earth only the patient. Its motion round its axis. and round the sun, and its inclining

inclining northward and southward at different times, are all produced by the action of the light going outward, and the spirit returning inward.

5. The Densities, which form the extremity of the whole system of nature; the dense, gross air, out of which the fine ether is extracted, and into which it returns. The heavens will naturally be grosser and grosser, the farther from the sun, till perhaps at the utmost extremity, they are condensed into an immoveable solid.

These are the constituent parts of the heavens. And hence we have reason to conceive, that all these parts, (the sun, moon and stars excepted) are no other than the different states into which the ethereal fluid does or may pass. For the *darkness* is the fine atoms of the heaven in a state of inactivity. The *spirit* is the grosser parts of the heavens or masses compressed together; while the *light* is the atoms or finest part of the ether in swift motion. At the center, the commotion is greatest, and gradually decreases towards the circumference, where the ether is very much condensed, and this is called the *density*.

He farther supposes, that the Sun is the center of the whole universe; that the fixed stars are all placed in the density, not far from each other, and abundantly nearer the earth, than common astronomers imagine, and that their use is not to perform the office of suns to other planets, but to assist in that cold region, to supply in some degree, the want of the solar fire.

Perhaps it may not be unacceptable to the serious reader, to give a more particular account of this ingenious hypothesis, in the words of a later writer. The sum of what Mr. Hutchinson
avers,

avers, is, That beside the differently formed particles of which the earth, and the several solid substances in it, and in the other orbs, are composed, God at first created all that subtle fluid which now is, and from the creation has been, in the condition of *fire, light or air*, and goes under the name of *the heavens*.

The particles of this fluid (which he calls atoms) when they are single and uncompound, are inconceivably minute, and so subtle as to pervade the pores of all substances whatever, whether solid or fluid. When they are pushed forward in strait lines, by the action of fire, or are reflected or refracted in strait lines, they produce *light*, and are so called. When the interposition of opaque *bodies* hinders their progress in strait lines, they pass, but cease to produce light.

These particles, which when moving in strait lines produce light, and when collected and put into another sort of motion, produce fire, when the force impelling them ceases to act with vigour, and when their motion is retarded, cohere in small masses or grains, which Mr. Hutchinson calls *spirit* or *air*, and is of the same kind and texture, with that air, which we daily breathe.

The sun, fixed at the center of this system, is included in a vast collection of this subtle matter, in the form of fire, which continually melts down all the air that is brought into it from all parts of the system, into atoms, and with an immense force sends it forth, in perpetual streams of light, to the circumference. The whole space comprehended within this, is absolutely full.

The matter thus melted down at the orb of the sun, moves outward to the circumference, and being

being forced by the particles which are concentered into air at the utmost extremities, returns toward the sun, where the fluid, being most subtle, gives least resistance, and takes up the place that the light left.

And therefore this uninterrupted flux of matter from the sun in light, in place of being an expence which would necessarily destroy that orb (an insupportable objection, Mr. Hutchinson thinks, to Sir Isaac Newton's scheme,) is the very means of preserving it, and every thing else in this system, in its action and vigour, by pressing back perpetual supplies of air, to be melted down into light, which produces a continual circulation. These perpetual tides of matter outwards and inwards, in every point, from the center to the circumference, produce that constant gyration in the earth, and the planets round their own center, and round the sun.

Besides the rotation of the orbs, the adverse motion of the light pushing toward the circumference, and the air pushing toward the center with immense force, brings that compressure on all the bodies it meets, that binds together solids, keeps fluids as they were, causes the rising of water, the production of vegetables and animals, and in short produces all the effects usually ascribed to gravitation or attraction; continues motion without the assistance of the unmechanical principle of projection, and is indeed the real cause of almost all the effects and phænomena in nature.

As immensely different as this is, from all the other systems of astronomy, very probable arguments are alledged in confirmation of it. And more than probability, I doubt, we shall never attain,

attain, with regard to things at so great a distance from us.

But what a strange discovery is that, which has been lately communicated by an eminent professor to the Royal Society? " Having carefully examined, the modern observations of the sun, with those of some centuries past, though I have gone no farther back than the fifteenth century, yet I have observed that the motion of the sun, (or of the earth) is sensibly accelerated since that time, so that the years are shorter now than formerly. The reason of this is very natural. For if the earth in its motion suffers some resistance (which cannot be doubted since the space through which the planets pass, is full of some subtle matter, were it no other than light) this resistance will gradually bring the planets nearer and nearer the sun. And as their orbits thereby become less, so their periodical times will be diminished. Thus in time the earth would come within the regions of Venus, then of Mercury, where it would necessarily be burnt. Hence it is manifest, that the planetary system cannot last for ever in its present state; as also that this system must have had a beginning; otherwise there must have been a time when the earth was at the distance of Saturn: consequently no living creature could subsist there. This then is a clear proof, that the world in its present state had a beginning, and must have an end.

We may likewise find reason to think, from the action of Jupiter on the earth, that the earth's revolution round its axis, continually becomes more and more rapid. For the force of Jupiter so accelerates the motion of the earth round the sun,

fun, that the diminution of the years would be sensible, if the diurnal motion had not been accelerated nearly in the same proportion.

It is another observation of Astronomers, that the sun does not shine as long on one side the line as on the other: that he stays longer in the six northern signs, than in the six southern: so much longer, as to make no less a difference, than that of nine days. How is this? Did the earth always obvert her northern hemisphere to the sun so much longer than the southern? Or has she gradually warped so much to one side, in a course of near 6000 years?

But over and above the Sun's motion round his own axis, in 25 days, 15 hours, he has another motion. There is a certain point, which is the true or common center of all the planetary motions, not quite a semi-diameter of the sun distant from its center. About this point, the sun and all the planets move; but in what time is uncertain.

9. Let us consider more closely, the advantages arising to us by the *Rotation* of the Earth about its own axis. We are so made, that once in sixteen or twenty hours at most, we require a time for relaxation. And generally in healthful people this time is pretty equal, between six and eight hours. The storehouses of our spirits, will not permit a longer application than twenty hours, without injury to our constitutions. And at least six hours are required to fill them again.

It was likewise necessary that the air should be cool and temperate, during the time of this rest;
for

for we generally find those that sleep while the sun is above the horizon, the worse for it, the sun and the heat exhaling the natural perspirations too violently, and raising too quick a motion in the blood. And though we generally perspire more in the night, yet the perspiration is more natural and less violent, and more according to the necessities of our constitutions in the night than in the day. Besides, the darkness is less subject to noise and disturbance than the day. Now all these things are wonderfully provided for, by the Rotation of the Earth about its axis. For thereby we have the vicissitudes of day and night, the day for spending our spirits, the night to recruit them; as also for nourishing the muscles, bones, channels, and other parts of the body; for the business of nutrition is mostly, if not altogether, performed in the time of rest. Likewise, how comfortable and refreshing are the cool breezes of the night; and the trade-winds to those that live under the equatorial parts? Without which, life would both be exceeding short, and very grievous.

These winds, are the necessary effect of the Rotation of the earth about its axis, which under the line makes the rays of the sun direct and equal all the year round; so that these parts being constantly under the sun's influence, his heat rarifies one part of the air, and the cooler and heavier part presses upon the hotter, and so makes a continual wind in his course from east to west.

Moreover, let us reflect upon our vegetables, which are the support of animals; the sun rarifies and consequently raises the sly vegetable juices,

juices, at the roots of the tender seeds, and thereby forces the folded branches to expand and enlarge. Now, were the sun constantly shining upon them, these juices would not be at liberty to settle, and consolidate in the fit places of the branches; but would be still rising higher and higher, till at last they burst the canals; whereas by this vicissitude of heat and cold, what is raised in the day time, has time to settle and consolidate in the night. Its cold turns the thin juices into sily substances, which the supervening heat, by exhaling the watry parts, hardens and fixes. On the other hand, had not the earth moved upon its axis, but only turned round the sun in its annual period, we had not only lost all these advantages, which are so necessary for both animals and vegetables, but had suffered also such inconveniences, as neither of these could possibly bear. For near half the year, we should have been in perpetual darkness, the consequence of which would have been, that baleful damps, by the preceding heat, generated and raised, would have fallen, which would have stifled all animals. Or had they survived that, snow, ice, and frost, would not only have locked up all fluids, but would have froze the blood and spirits in the channels of all the animals we are acquainted with.

Again, in the enlightened half of the year, we should have had huge deluges of water, from the preceding snow, which likewise would have produced suffocating mists. Next, all our ground would have turned into a stiff, stinking puddle, being in a manner dissolved by the snow water. Then would sultry heats and a burning air, have scorched,

scorched and chapped the earth, and galled the animal tribes, so that they would have found rest, neither in houses nor dens, till at last, the blood and spirits of all the animals of our globe, would be quite exhaled, or by the violent agitation thereof, they would turn delirious.

Upon all these accounts, the Rotation of the Earth, about her axis, is one of the most signal instances of Divine Wisdom.





C H A P. II.

Of the HEAVENLY BODIES, in particular.

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| 1. <i>Of the Sun,</i> | 8. <i>Saturn,</i> |
| 2. <i>Mercury,</i> | 9. <i>Comets,</i> |
| 3. <i>Venus,</i> | 10. <i>The fixed Stars:</i> |
| 4. <i>The Earth,</i> | 11. <i>Reflections.</i> |
| 5. <i>The Moon,</i> | 12. <i>Doubts concerning</i> |
| 6. <i>Of Mars,</i> | <i>the modern Astro-</i> |
| 7. <i>Jupiter,</i> | <i>nomy.</i> |

1. **T**HE very same effects which we observe daily in Fire, we observe also in the Sun. It shines, it warms, it burns. Viewed with a telescope it appears like an ocean of fire or melted metal. Hence many suppose, that the spots appearing thereon and changing continually, are as it were the drops and scum of that metal, which it throws out from time to time. But it is more probable, some of those spots are clouds, formed out of the solar exhalations. And if exhalations rise out of his body, and are suspended at a certain height from it, then the sun must be encompassed with a fluid, analogous to our atmosphere. Some of these spots dissolve and disappear, in the very middle of the Sun's disk : that is, the exhalations sometimes rise, sometimes fall back to the Sun.

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But there is another kind of spots which regularly revolve, once in seven and twenty days. Or to speak more properly, the Sun himself revolves nearly in that time, round his own axis, together with his atmosphere.

But over and above this motion on his own axis, "We are not sure, says Mr. Huygens, whether the Sun be a solid or liquid globe. I rather think it liquid, which the equal distribution of his light to all parts is an argument for. That very small inequality on his surface, discovered by the telescope, which has made some men imagine they saw huge mountains of fire, is entirely owing to the trembling motion of the vapours our atmosphere is full of, particularly near the earth. And this is likewise the cause of the stars twinkling.

"The dark spots in the Sun I have often seen: but those bright spots of which many speak, I never was able to discover: so that I cannot but doubt of their existence. Nor do I apprehend there is any thing in or upon the Sun, brighter than the Sun itself. Indeed it is not pretended that these bright spots are any where, but just about the dark ones. And it is no wonder, the parts which are near the dark, should appear somewhat brighter than the rest."

And hence it is, that those spots being viewed obliquely, near the edge of the Sun, appear narrow and oblong. He is supposed to be abundantly larger than the earth. When the moon passes between the earth and the Sun, so as to intercept his rays, he is said to be *eclipsed*. This happens only at the time of the new moon, because it is then only she passes between the sun and the earth. Yet not at every new moon, be-
cause

cause she generally declines either to the north or south.

No solar eclipse can be universal, the moon being too little to overshadow the whole earth. Nor does any eclipse appear the same in all places, but is total in one, and partial in another. In most solar eclipses, the moon is covered with a faint, dawning light, which is owing to the reflection of the light from the illuminated parts of the earth. In total eclipses the moon's edge is seen surrounded by a pale circle of light, which is at least a probable indication of a lunar atmosphere.

When the earth is interposed between the moon and the Sun, then the moon is eclipsed. This is only at the time of the full moon. Even in the midst of the eclipse, the moon has a faint light which is reflected by the atmosphere of the earth. And to the shadow of this it is owing, that she grows paler and dimmer, before she enters into the shadow of the earth.

2. The planet nearest to the sun is Mercury, which is the smallest of all, supposed to be twelve times less than the earth. It moves round the sun in about three months, and is believed to be the most dense of all the heavenly bodies. It sometimes moves between the earth and the sun. And from its various appearances we may certainly infer, that it has no light of its own, but shines by reflection only.

3. The next to Mercury is Venus, whose appearances likewise change in the same manner as the moon's. It is supposed to be something less than the earth, and compleats its period round the sun, in nearly seven months. From its situation
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we may judge, it is more dense than the earth, but more rare than Mercury.

4. Next to Venus is the Earth, which moves round its own axis from west to east in twenty-four hours, and round the sun in three hundred and sixty-five days five hours and near forty-nine minutes.

The difference of seasons, as well as the different degrees of heat and cold, depend on the different positions of the earth with respect to the sun. The natural state of this globe seems to be what we call temperate. This is what secures springs and other bodies from being frozen. But the obliquity and perpendicularity with which the rays of the sun fall on the air, are varying continually, according to which the warmth of the air is continually lessening or encreasing. Likewise the continuance of the sun's presence, with the slowness of his motion, naturally increase heat; as his absence and the swiftness of his motion, naturally increase cold. Yet this rule does not always hold. There are many accidents that prevent it: such as the situation of hills, and the declivity of land, towards the north or south. Clouds also sometimes reflect heat, and water-clouds cool the air. South or south west winds, if without rain, increase warmth; east or northerly winds occasion cold. Whenever smooth water reflects the sun's rays, it much increases heat. And indeed all smooth bodies which reflect light, reflect heat along with it, and that more or less, according to the closeness of the pores, and the extent convexity, or concavity of their surface.

All parts of the earth enjoy nearly the same quantity of the sun's presence in the same space of a year. And yet how widely different

is the quantity of heat, in some from that in others? But it is not, as any one would imagine greatest under the line. This is prevented by the swiftness of his motion. For the nearer he approaches to it, the swifter is his motion from east to west, from north to south, and from south to north. He passes seven degrees, from three and a half south latitude to three and a half north, in eighteen days: whereas at twenty degrees north latitude, he spends an whole month in going three degrees and a half, and another month in returning: so that he is as near the tropic for sixty-seven days, as he was to the line for eighteen. And hence the heat is considerably greater under the tropic, than it is under the line.

5. The Moon moves round the earth in about twenty-eight days, and with the earth round the sun in a year. Yet it always turns nearly the same side to the earth, whence we always observe the same inequalities in its surface. It does not appear that she moves at all round her own axis. None now doubts of the moon's being an opaque body: and the spots and unevennesses, which constantly appear upon it, have been judged by some to be vallies, mountains, lakes, and seas.

Her days and months are of an equal length, which we do not observe of any other body in the heavens. That her day is equal to her month, appears hence. Since in whatever part of her orbit she is, the same face and the same spots are always observed, without the least variation, she must have such a motion round her own axis as turns every moment so much of her surface from our view, as is turned to us by her periodical mo-

tion: that is, she must move in the same time about her axis, as she does about the earth.

Half at least of the Moon is always enlightened by the sun, but as it is continually changing its situation, the whole of the enlightened part is not always toward us, and therefore she exhibits to us various appearances. When she begins to recede from her conjunction with the sun, and to emerge out of his rays, a small portion of her enlightened part is seen, and appears as it were horned. But the farther she recedes from the sun, the more of the enlightened part appears, till about the fourteenth day, being just opposite to him, she shews us her entire hemisphere. In the same manner she appears to decrease, while she is approaching the sun. The Moon is supposed to be forty-five times smaller than the earth.

The Moon has sometimes disappeared in a clear sky, so as not to be discoverable by the best glasses. This Kepple observed in the year 1580 and in 1583: Hevelius in 1620, as did Ricciolus and many others at Bologna. Many people throughout Holland observed the same, April 14, 1642. December 23, 1703, there was another total obscuration. A little before it, she appeared at Arles of a yellowish brown, at Avignon, ruddy and transparent. At Marseilles one part was ruddy, the other dusky, till she wholly disappeared. I do not find that the boldest philosophers attempt to account for this.

It is now almost universally supposed, that the Moon is just like the earth, having mountains and valleys, seas with islands, peninsula's and promontories, and a changeable atmosphere, wherein vapours and exhalations rise and fall. And hence
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it is generally inferred, that she is inhabited like the earth, and by parity of reason, that all the other planets, as well as the earth and moon, have their respective inhabitants. But after all comes the celebrated Mr. Hugen, and brings strong reasons why the Moon is not and cannot be inhabited at all, nor any secondary planet whatever. Then I doubt we shall never prove that the primary are: and so the whole ingenious hypothesis, of innumerable suns and worlds moving round them, vanishes into air.

It may not be unacceptable to the reader, to see the sum of his reasonings on this head. " One would think that the Moon which is so near us, and may by a telescope be so accurately observed, should afford us matter of more probable conjecture, than any of the remoter planets. But it is quite otherwise. Only this we may venture to say, that all the attendants of Jupiter and Saturn are of the same nature with our Moon, as going round them, and being carried with them round the sun, just as the Moon is with the earth. Therefore whatever we may reasonably affirm or conjecture, with regard to our Moon, must be supposed with very little alteration to belong to the Satellites of Jupiter and Saturn.

" The surface of the Moon is found, even when we use the shortest telescopes, to be diversified with long tracts of mountains, and again with broad valleys, For in those parts opposite to the sun, you may see the shadows of the mountains, and often the round valleys between them, with an hill or two rising out of them. But I cannot find any thing like sea

there, notwithstanding what many affirm. For those vast countries which appear darker than the others, commonly taken for seas, are discovered with a good long telescope, to be full of little round cavities: the shadow of which, falling within themselves, makes them appear of that colour. And those large champains, if you look carefully upon them, you will find not to be always smooth and even. Now neither of these things can agree to the sea. Therefore it is far more probable, that those plains in her which seem brighter than the other parts, consist of a whiter sort of matter. Nor do I believe, that there are any rivers: for if there were, they could never have escaped our observations. Especially if they run between the hills, as our rivers do. Nor have they any clouds to furnish rivers with water. For if they had, we should sometimes see one part of the Moon darkened by them and sometimes another, whereas we have always the same prospect of her.

It is certain moreover that the moon has no air or atmosphere surrounding it. For then we could never see the very outermost rim of the Moon so exactly as we do when any star goes under it, but its light would terminate in a faint, gradual shade, and there would be a sort of down as it were about it. Not to mention, that the vapours of our atmosphere consist of water; and consequently where there are no seas, there can be no such atmosphere. This is the grand difference between the Moon and us. Were there seas and rivers therein, we might easily believe that it had all the other furniture which belong to our earth. But how can plants or animals, all whose nourishment comes from liquid bodies, thrive, in a dry waterless soil?"

"Does

“ Does then the Moon serve for nothing but to give us light in the night ? And do all these moons round Jupiter and Saturn, answer no other purpose ? I do not know what to say, because I know of nothing like them to found a conjecture upon. Perhaps they may have some plants and animals, which have some nourishment of a different kind from ours. Perhaps they may have moisture enough to cause a mist or dew, which may suffice for the herbs that grow there. But these are mere guesses, or rather doubts. And yet they are the best we can make, concerning either our own Moon or those which attend Jupiter and Saturn.”

What benefits do we receive from our Moon ? First, the supplying light in the night-time, for at least three fourths of the year. Now how comfortable and delightful a thing this is, travellers and voyagers can best tell. Curiosity, ambition, luxury, and sometimes necessity have made it unavoidable, that some part of mankind should be travelling by land and sea, in the night seasons. How pleasant then is it, to have a light held out from Heaven, to guide our steps, to direct us in our course, and to point out to us how our time wears out.

Secondly, she raises our tides twice in twenty-four hours, which is absolutely necessary towards the subsistence both of animals and vegetables. Every body knows that a lake that has no fresh water running into it, will by the heat of the sun in a few months, and its stagnation, turn into a stinking, rotten puddle, sending forth nauseous and poisonous steams. And though many thousand rivers daily run into the sea, yet they are very

inconsiderable in respect of the vast ocean of salt-water ; and would by no means hinder its stagnation, and consequently its corruption and stinking. Now suppose the ocean stagnated, the first effect would be, all the places towards the shores, would be wrought upon by the sun, and turned to a memphitis. Then it would get farther till the whole were become more baneful and poisonous than the lake of Sodom and Gomorrah. Hereby the fishes would first be destroyed, and afterwards the plants and animals ; but by this action of the Moon, the waters are lifted up on a heap, as it were, and then let fall again, whereby the waters near the shores are constantly secured from stagnation and corruption, and the beginning of malady stifled. This perpetual change of new water on the shores, keeping any one portion thereof, from being exposed to the sun long enough to have its mixture corrupted. Now what a noble contrivance have we here. By appointing an attendant to our earth, all the animals and vegetables are preserved from certain destruction. Though indeed to the full effect of this wise design, the salt of the sea does very much contribute ; as there are many saline rocks and mountains dispersed over the foundations of the great ocean. Besides this, how many conveniencies for our navigation in rivers and harbours does this ebbing and flowing of the sea afford ? Yet if our earth had more than one Moon attending it, we should receive more damage than advantage by it ; for though hereby our light in the night might be augmented, yet at their conjunctions and oppositions with one another, and with the sun, we should have tides that would raise the waters over too much of our dry land ; and in their quadratures

ratures we should have no tide at all. Again, if our Moon were bigger or nearer the earth, or if we had more than one, at any tolerable distance from us, we should be every now and then in hazard of being stifled by the noxious streams arising from the ocean. From all which it is evident, how wisely our flatelite has been contrived for our purposes.

6. Mars, as well as Venus, Mercury, and the Moon, has various appearances, more or less full, as it is variously placed, with regard to the sun and the earth. Spots are observed on his surface also, from the regular motion of which we learn, that he revolves round his axis from west to east, in twenty-four hours and forty minutes. He moves round the sun in two years, and it is thought to be eight times smaller than the earth.

7. Jupiter is encompassed from west to east with two or three lucid Belts, not always appearing alike. In one of them a spot is constantly observed; and they regularly move from west to east. Hence we learn, that he revolves round his axis, which he does in nine hours and fifty-six minutes. He is likewise attended by four smaller planets or Satellites, like our Moon. Each of these move round him in its stated period, and all move with him round the sun in twelve years. Jupiter is supposed by some to be twenty-five, by others 4096 times larger than the earth.

8. The highest planet Saturn is encompassed with a broad Ring, which is not contiguous to his body, but is suspended over him equally distant from every part of his surface. He has five

satellites or moons, moving round him in their stated periods. The brightest of these, which is the fourth, was first discovered by Mr. Huygens, in the year 1655. The rest were discovered by Cassini. And I have reason to think, says Mr. Huygens, there are one or two more still behind. For between the fourth and fifth there is a distance not at all proportionable to that between all the others. Here it is propable, there may be a sixth. And there may not improbably be another, without the fifth, which has hitherto escaped us. For we can never see the fifth but in that part of its orbit, which is towards the west.

Saturn himself revolves with them round the sun in about thirty years. He is supposed to be fifteen times bigger than the earth.

If we compute the magnitude of the planets in number of miles, the diameter of the moon is supposed to be 2175 miles, that of Mercury, 2748, that of Mars 4875, of the Earth, (and nearly of Venus) 7967, of Saturn 93451, of Jupiter 130653; and that of the sun 822148.

With regard to their distance from the earth, there is such an immense difference in the calculations of astronomers, even with respect to the distance of the sun (which some *demonstrate* to be ninety millions of miles, others to be not three millions from the earth: that it is wisest to confess our ignorance, and to acknowledge we have nothing to rest on here, but mere uncertain conjecture.

9. Comets are opaque bodies, which emit numerous rays sometimes forwards, sometimes backwards, sometimes all round the body of the comet. Now they sink near the body of the sun: then they rise far beyond the orb of Saturn. Some suppose

suppose them to be imperfect planets, or such a chaos of unformed matter, as may hereafter be formed into an earth like ours. Probably those rays which they emit, are only vapours, by which the rays of the sun are refracted to us.

Hence they have a different appearance, according as they are differently situated with regard to the comet: which is hereby confirmed that the nearer they are to the sun, the more those rays are increased, and the farther they recede from it, the more those are diminished. And hence some imagine that fixed stars, covered with vapours and spots, become comets. It is more probable that comets, like planets have their regular periods: although they frequently escape our observations, as not revolving but in a long term of years.

They are distinguished from other stars by a large train of light, which is always opposite to the sun, and grows fainter and fainter the farther it is from the body of the comet. When a comet moves from the sun it is said to be *bearded*, because that light is seen before it. When it moves toward the sun, the train follows it, and is called its *tail*. When the comet and sun are opposite, (the earth being between them) the train is hid behind the body of the comet, except a little that appears round it, and is termed its *hair*.

Sir Isaac Newton has proved, that the heat of the sun to the Comet in December 1680, was to his heat with us at Midsummer, as 28000 to one: and that the heat of the body of the Comet was near 2000 times greater than that of red-hot iron.

After having acquired so immense an heat, it must be a long time in cooling. Sir Isaac computes, that a globe of red-hot iron 200 times as
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large as the earth, would scarce be cool in 50,000 years. If then the Comet be supposed to cool an hundred times as fast as red-hot iron, yet since its heat was two thousand times greater, supposing it of the bigness of the earth, it would not be cool in a million of years.

Comets seem to be a peculiar kind of planets, which move in very oblique orbits, and persevere in their motions, even against the course and direction of the other Planets. Their tails are doubtless vapours emitted by the comet when heated by the sun. Yet they do not ascend swiftly from it, and then presently disappear; but are permanent columns of exhalations, gathered from the Comet by a gentle motion, and in a great space of time, which then move with it through the celestial regions.

One great use of Comets probably is, to give moisture to the planets. By their vapours the water spent in them, may be supplied and recruited. All vegetables grow from fluids. But when they putrify, great part of them turn into dry earth: hence the quantity of dry earth must continually increase, and the moisture of the globe decrease. Add to this, that immense quantities of watry vapours, are continually arrested in the polar regions, and falling down form mountains of eternal snow, and rocks of ice that thaw no more. By both these means the moisture of the planets continually decreasing, must in process of time entirely fail, if it had not a seasonable supply, from some other part of the universe. Comets therefore are so far from being superfluous, much more from being blemishes in the universe, that it may be doubted whether either the animals or vegetables

vegetables of the earth could long subsist without them.

And indeed, if the uses assigned to the Comets by Sir Isaac Newton be real, as they are not improbable, nature by the supplying the deficiency and expences of all sorts of fluids necessary to the earth: I mean not only light and heat to the sun, and watery vapours to our atmosphere, but the most subtle, most useful, and necessary part (towards life and vegetation) to the air; then these wandering frightful bodies, may be justly conceived joining in the chorus, and loudly resounding the common Hallelujah.

But the astronomy of Comets, says Mr. Brydon is clogged with very great difficulties, and even some seeming absurdities. It is difficult to conceive, that these immense bodies, after being drawn to the sun, with the velocity of a million of miles in an hour, when they have at last come almost to touch him, should then fly off from his body, with the same velocity they approached it, and that too, by the power of this very motion, that his attraction has occasioned. The demonstration of this, I remember is very curious and ingenious; but I wish it may be entirely free from sophistry. No doubt, in bodies moving in curves round a fixed center, as the centripetal motion increases, the centrifugal one increases likewise: but how this motion, which is only generated by the former, should at last get the better of the power that produces it, and that too, at the very time this power has acquired its utmost force and energy, seems somewhat difficult to conceive. It is the only instance I know, wherein the effect increasing regularly with the cause; at last, whilst

the cause is still acting with full vigour, the effect entirely gets the better of the cause, and leaves it in the lurch. For the body attracted, is at last carried away with infinite velocity from the attracting body. By what power is it carried away? Why, say our philosophers, by the very power of this attraction, which has now produced a new power superior to itself: to wit, the centrifugal force. However, perhaps all this may be reconcilable to reason; far be it from me to presume to attack so glorious a system as that of attraction. The law that the heavenly bodies are said to observe, in describing equal *æreas* in equal times, is supposed to be demonstrated, and by this it would appear, that the centripetal and centrifugal forces alternately get the mastery of one another.

However, I cannot help thinking it somewhat hard to conceive, that gravity should always get the better of the centrifugal force, at the very time that its action is the smallest, when the Comet is at the greatest distance from the sun; and that the centrifugal force should get the better of gravity, at the very time that its action is the greatest, when the Comet is at its nearest point to the sun.

To a common observer it would rather appear, that the sun, like an electric body, after it had once charged the objects that it attracted, with its own effluvia or atmosphere, by degrees loses its attraction, and at last even repels them, and that the attracting power, like what we likewise observe in electricity, does not return again till the effluvia imbibed from the attracting body are dispelled or dissipated; when it is again attracted, and so on alternately. For it (appears at least to an unphilosophical observer) somewhat repugnant

to reason, to say, that a body flying off from another body some thousands of miles in a minute, should all the while be violently attracted by that body: and that it is even by virtue of this very attraction that it is flying off from it. He would probably ask, What more could it do, pray, were it really to be repelled?

Had the system of electricity, and of repulsion, as well as attraction, been known and established in the last age, doubtless the profound genius of Newton would have called it to his aid, and perhaps accounted in a more satisfactory manner for many of the great phænomena of the heavens.

To the best of my remembrance, we know of no body that possesses, in any considerable degree, the power of attraction, that in certain circumstances does not likewise possess the power of repulsion: the magnet, the tourmalin, amber, glass, and every electrical substance. Now from analogy, as we find the sun so powerfully endowed with attraction, why may we not likewise suppose him to be possessed of repulsion? Indeed this very power seems to be confessed by the Newtonians, to reside in the sun in a most wonderful degree; for they assure us he repels the rays of light with such amazing force, that they fly upwards of 80 millions of miles in seven minutes. Now why should we confine this repulsion to the rays of light only? As they are material, may not other matter brought near his body, be affected in the same manner? Indeed one would imagine, that their motion alone would create the most violent repulsion; and that the force with which they are perpetually flowing from the sun, would most effectually prevent every other body from approaching

approaching him ; for this we find is the constant effect of a rapid stream of any other matter. But let us examine a little more his effects upon Comets. The tails of these bodies are probably their atmospheres, rendered highly electrical, either from the violence of their motion, or from their proximity to the sun. Of all the bodies we know, there is none in so constant and so violent an electrical state, as the higher regions of our own atmosphere. Of this I have long been convinced ; for send up a kite with a small wire about its string, only to the height of twelve or thirteen hundred feet, and at all times it will produce fire, as I have found by frequent experience ; sometimes when the air was perfectly clear, without a cloud in the hemisphere ; at other times, when it was thick and hazy, and totally unfit for electrical operations below. Now as this is the case at so small a height, and as we find the effect still grows stronger, in proportion as the kite advances (for I have sometimes observed, that a little blast of wind, suddenly raising it about an hundred feet, has more than doubled the effect) what must it be in very great elevations ? Indeed we may often judge of it from the violence with which the clouds are agitated, from the meteors formed above the region of the clouds, and particularly from the aurora borealis, which has been observed to have much the same colour and appearance as the matter that forms the tails of Comets.

There is a species of Comets, says the same gentleman, that have not tails : these are certainly bodies of a very different nature from those with tails, to which indeed they appear even to bear a much less resemblance than they do to planets :
and

and it is no small proof of the little progress we have made in the knowledge of the universe, that they have not as yet been distinguished by a different name.

This is the third kind of body that has been discovered in our system, that all appear essentially different from each other, that are probably regulated by different laws, and intended for very different purposes. How much will posterity be astonished at our ignorance, and wonder that this system should have existed for so many thousand years, before we were in the least acquainted with one half of it, or had even invented names to distinguish its different members.

I have no doubt, that in future ages the number of the Comets, the form of their orbits, and time of their revolutions, will be as clearly demonstrated, as that of the planets. It is our countryman Dr. Halley, who has begun this great work, which may be considered just now as in its earliest infancy. These bodies too, with thick atmospheres, but without tails will likewise have their proper places ascertained, and will no longer be confounded with bodies to which they bear no resemblance or connection.

Comets with tails have seldom been visible, but on their recess from the sun. It is he that kindles them up, and gives them that alarming appearance in the heavens. On the contrary, those without tails, have seldom, perhaps never, been observed but on their approach to him. I do not recollect any whose return has been tolerably well ascertained. I remember indeed, a few years ago a small one, that was said to have been discovered by a telescope, after it had passed the sun, but never

ver more became visible to the naked eye. This assertion is easily made, and nobody can contradict; but it does not at all appear probable, that it should have been so much less luminous after it had passed the sun, than before it approached him; and I will own, when I have heard that the return of these Comets had escaped the eyes of the most acute Astronomers, I have been tempted to think that they did not return at all, but were absorbed in the body of the sun, which their violent motion toward him seemed to indicate. Indeed, I have often wished that this discovery might be made, as it would in some measure account for what has as yet been looked upon as unaccountable; that the sun, notwithstanding his daily waste from enlightening the universe, never appears diminished either in size or light. Surely this waste must be immense, and were there not in nature some hidden provision for supplying it, in the space of six thousand years. Supposing the world to be no older, the planets must have got to a much greater distance from his body, by the vast diminution of his attraction: they must likewise have moved much slower, and consequently the length of our year must have been increased. Nothing of all this seems to be the case; he neither appears diminished nor our distance from him increased; his light, heat, and attraction seem to be the same as ever; and the motion of the planets round him is performed in the same time; of consequence, his quantity of matter still continues the same. How then is this vast waste supplied? May there not be millions of bodies attracted by him from the boundless regions of space, that are never perceived by us? Comets on their road to him, have several times been

been accidentally discovered by telescopes that were never seen by the naked eye. Indeed the number of black spots on the sun, seems to indicate, that there is always a quantity of matter there, only in preparation to give light, but not yet refined and pure enough to throw off rays like the rest of his body. For I think we can hardly conceive, that any matter can remain long on the body of the sun without becoming luminous; and so we find these spots often disappear; that is to say, the matter of which they are composed is then perfectly melted, and has acquired the same degree of heat and light as the rest of his body. Even in glass houses and other very hot furnaces; most sorts of matter very soon acquire the same colour and appearance as the fire, and emit rays of light like it. But how much more must this be the case at the surface of the sun. When Newton computes, that even at many thousand miles distance from it, a body would acquire a degree of heat two thousand times greater than that of red hot iron. It has generally been understood, that he said the great Comet really did acquire this degree of heat: but this is certainly a mistake: Sir Isaac's expression, to the best of my remembrance, is; that it might have acquired it. And if we consider the very great size of that body, and the short time of its perihelion, the thing will appear impossible; nor indeed do I think we can conceive; that a body only as large as our earth, (and the spots on the sun are often much larger,) could be reduced to fusion even on his surface, but after a considerable space of time.

Now it seems to be universally supposed, that the rays of light are really particles of matter, proceeding from the body of the sun. If so it is absolutely

folutely neceffary that we fhould fall upon fome fuch method of fending him back a fupply of thofe rays, otherwife let his flock be ever fo great, it muft be exhaufted.

10. It is commonly fuppofed, that the fixed Stars are fo many funs, fhining with their own light : and that each of them has a fet of planets moving round it : as the earth, and the other planets do round our fun. It may be fo, or it may not ; for we know nothing about them : nor is it poffible we fhould know more. For even when viewed with the beft telescopes, they appear no larger than they do to the naked eye. They are divided, according to their fize, into ftars of the firft, fecond, and fo on to the fixth magnitude.

Even a good eye feldom fees more than an hundred Stars, at a time in the cleareft heaven. The appearance of vaft numbers in winter nights. is a mere deception of our fight, occafioned by our viewing them confufedly, not in any regular order.

Yet are they really almoft infinite. For a good telescope directed to almoft any part of the heavens, discovers numbers unfeen by the naked eye, particularly in the *milky way* : which is indeed nothing elfe but an afsemblage of Stars, too remote to be feen fingly, but fo clofe to each other, as to give that brightness to fo large a part of the heavens.

There are fix or feven of thefe *nebulous Stars*, as they are called. They are indeed compound ftars, confifting of multitudes of fingle ones. In fome of thefe appears a bright lucid part, in
which

which some stars appear, as from a white cloud. and these are reckoned to be regions of a peculiar nature, enjoying an uninterrupted, everlasting day.

The *seven Stars* so called, probably were seven once; but one of them became extinct, even before the time of Augustus Cæsar: and no more than six have appeared ever since. But these likewise, when viewed through a good telescope, are more than can easily be numbered.

An hundred and twenty five years before Christ Hipparchus discovered a new star. In 1572 Tycho Brahe observed another. Its magnitude at first exceeded the biggest of our stars. It equalled that of Venus when nearest the earth, and was seen in fair day light. It continued sixteen months, toward the end of which it grew less till it totally disappeared. We have an account of one appearing at least thrice before, at the interval of 150 years. Probably it was the same star, and will return at the stated time.

Many other new Stars have been observed in this century to appear and disappear; and it is certain from the old catalogues, that many of the antient Stars are not now visible.

There are now wanting two stars of the second magnitude in the ship Argo, which were seen till the year 1664. But there was not the least sign of them in 1668. Accurate Astronomers have observed many more such changes in the fixed Stars, to the number of an hundred.

Are these temporary Stars a sort of planets?
Are they fixed Stars, which being covered with spots

spots like those observed on the sun, lose their brightness, and consequently disappear? Or are they Comets, which take so vast a time to perform their revolutions, as seldom to have their returns perceived?

11. It remains only to make some improvement of what has been observed, concerning the system of the universe. And First, we may observe the due *situation* of the heavenly bodies. 1, none of them interfere with each other. Had the universe been the work of any but the wise architect. there would have been many inconveniences in the situation of such a prodigious number of immense globes. Some would have been too near or too far off: some would have incommoded others. But instead of this, all the globes which fall under our notice, are set at such a due distance, as not only to avoid all violent concurrence, but not to shade each other, so as to hinder each other's kindly influence, or to occasion noxious ones. 2, as it is one great instance of the skill of an architect, to give due *proportion* to his works, so this abundantly appears in all the heavenly bodies that come under our cognizance. Curious order, and due and nice proportions are observed in their situations. The sun is placed in the center of his system, to give all his planets heat and light. Then follow the several planets surrounding him, not scattered at all adventures, but at due distances from the sun, as well as from one another. And this is discernable, not only the primary, but the secondary planets too: in the five moons that attend Saturn, and the four that accompany Jupiter.

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The wisdom of the Creator appears, Secondly; from the *motions* of the heavens and the earth. That these vast globes should move at all, proves some being that has power to put them in motion: seeing matter cannot move itself. And suppose them moved by the sun, the ether, or some other primary mover, still we must recur to some first Cause who was able to put the mover into motion. And this could be no other than the hand of the Almighty. What farther shews both his power and wisdom, is that those motions are not at random, or in inconvenient lines and orbs, but such as manifest the deepest counsel. That every planet should have as many and various motions. as the world and its inhabitants have occasion for, must be the work of a wise and kind, as well as omnipotent Creator.

In particular, the *diurnal* motion of these globes shews the wisdom of the Creator. Of what prodigious use is this? Were the planets always to stand still, half of each globe would be dazzled and parched with unceasing day, and the other half wrapt in everlasting darkness. Were this the case with our globe, a great part of it at least would scarce be habitable. It would neither agree with the state of man or other animals, nor of vegetables. How could the vapours be raised to supply the earth with cooling clouds and fruitful showers? How could the winds be excited to fan the atmosphere with their pleasant and healthful gales? How could vegetables be raised up by the kindly heat of the day, and tempered by the dews and cool of the night? How could men and other animals gather their food, and perform the various labours of the day, and then under
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the salutary influences of the night recruit themselves with rest and sleep?

And as the diurnal, so the *annual* motion of the heavenly bodies, is a clear manifestation of the Creator's wisdom: especially when we consider the different paths of their diurnal and annual motions. These lie not in a very different plane, nor in the same, but a little crossing one another: the diurnal, lying in or parallel, to the equator, the annual, at an inclination of twenty-three degrees and an half. A glorious contrivance this for the good of our globe, and for all the rest that have the same annual motion. For were the earth's annual motion to be always in the same plane with the diurnal, we might indeed be sometimes nearer to the sun than we now are. But we should miss of those kindly increases of day and night, which the approach of earth to one or the other pole occasions. This is likewise the great cause of summer and winter. Indeed one cause of them is, the longer or shorter continuance of the sun above the horizon. As it continues longer in summer, it increases the heat, as much as it lengthens the day: and just the contrary in winter. But the chief cause is, the oblique or perpendicular direction of the sun's rays. For 1. Perpendicular rays strike on any plane, with greater force than oblique. And 2. A greater number of rays fall within the same compass, in a perpendicular rather than in an oblique direction.

A farther manifestation of the Creator's wisdom we have in the *perpetuity, constancy, and regularity* of those motions. How without an Almighty guide

guide should those vast bodies continue their courses throughout all ages? How should they perform their usual stages, without the least intermission or disorder? What piece of clock-work under heaven, was ever comparable to this? How steadily do all these motions conspire, to answer the ends of divine providence, to dispatch the noble offices of the several globes, to comfort and cherish every thing residing on them, by the useful change of day and night, and the several seasons of the year.

We may learn the wisdom of God, Thirdly, from the Figure of the heavenly bodies, so well suited to the motions, and to the whole state and convenience of them. And 1. They are all nearly spherical: I say, nearly, to allow for their difference between their polar and equatorial diameter. Now this figure is both more capacious than any other, and more agreeable to a mass in motion, each part of it being at a due distance from the center of motion and gravity: besides, without this, there could have been no such agreeable alterations of day and night, of heat and cold. And as to our own globe, the winds could not have fanned the air, as now, but must have been greatly retarded, if not wholly stopt, by the angles and jettings out of other figures. Lastly, the waters would have had intolerable confluences; here too much, there none at all. So that instead of an habitable world, far the greatest part would have been a desert, or an useless bed of waters.

And all the parts of the earth are so distributed as may best minister to their several uses. Thus the two grand parts, the Solids and Fluids, instead of being jumbled into one mass, are admirably parted

parted, and as nicely disposed of in proper places. The strata conveying sweet water in all or most part of the world, consist of proper, pervious matter, remain distinct from the other strata, and lie at such due depths, as either to break out in fountains, or to be dug into for wells: all which is a manifest demonstration of the concern of a Wise Agent.

And not only the Planets are a demonstration of this, but the very *Comets* also: though their motions are so far from being always the same way, that they move sometimes contrary to each other. Their planes and directions lie every way, and their orbits are exceeding eccentrical. But this very eccentricity is an admirable contrivance of the Creator, to prevent their disturbing either the planets, or one another, by mutual attractions. By this means they have sufficient room to revolve in: and by ascending to very great heights, and spending almost all their time in the remote regions of the universe, at vast distances both from the planets and each other, they incommode neither. Whereas had they moved in the same plane with the planets, they would sometimes have come too near them: and possibly have disturbed *their* motions, or even dashed against them.

But what would all the planets have done, had they not been supplied with light and heat? And what an indulgent provision of these is made even for the most distant of them? See the sun, such a prodigious mass of fire, placed in the center of the system, to scatter his light throughout the whole, and to warm and cherish us by day:
and

and such a noble retinue of moons and stars, attending and assisting us by night ! And we see the same care of the Creator, extended to all the other planets. According to their several distances, they have proportionably a great number of moons, and Saturn a stupendous ring besides, to supply the decrease of light and heat. Who can help being amazed at such well-contrived, such stately works of God ? Who can partake of their beneficial influences, and not adore the wisdom and kindness of their Maker ?

One or two points, which have been lightly mentioned already, deserve a more particular consideration.

That he who dispenses existence at his will, should multiply, extend, enlarge, and add a kind of immensity to his works, is not properly what surprizes me ; at least my amazement is chiefly founded on my own extreme littleness. But what astonishes me most, is to see, that notwithstanding this my extreme littleness, he has vouchsafed to regulate his immense works, by the advantages I was to receive from them ! Thus he has placed the sun just at such a distance from the earth on which I was lodged, that it might be near enough to warm me, yet not so near, as to set it on fire.

The rays that proceed from a globe of fire, many thousand times bigger than the earth, must needs have an inconceivable force, while they remain close to each other. But they are more and more distant from each other, as they advance from their common center. toward the vast cir-

cumference they are to enlighten, and their force diminishes in proportion. Had the earth been placed, where these rays were still too numerous, and too near each other, it could never have borne their burning heat. Had it been placed farther off than it is, it would have received but a faint warmth, such as was insufficient for its usual productions. It stands in that very place where it is secured from all these inconveniences, and within the reach of every advantage,

The Heavens declare the grandeur and glory of God, from one end of the world to the other. But the sun alone affects us more than all the beauties the heavens can display to our sight: the heavens are only a pavillion to the sun. The richly embroidered veil which seemed to hide him from us for a season, is removed, when he advances. At first, he appears as a young bridegroom, coming out of his chamber. His splendor is then full of mildness, and he is easy of access. But he is commissioned to convey the heat and the life, as well as the light, every where. He darts more and more fire as he ascends. He passes from one end of the heavens to the other. There is nothing can either be hid from his light, or subsist without his heat. And by his penetrating fires he reaches those very places which are inaccessible to his rays.

And yet we need his absence at proper intervals, no less than we do his presence. For *night* and sleep are so connected, that when we want repose, we generally procure a kind of artificial night. Our senses are seldom unbent, but by the
removal

removal of that which agitates them. And this is the service for which night is appointed, and which it excellently well performs. It does not come in a blunt and abrupt manner, to extinguish the light of the day, and all on a sudden to rob us of the sight of the objects we are intent on: but advances only by slow steps, and brings on darkness by degrees. It is not till after reminding us of the necessity of taking rest, that it covers the face of nature.

During the time of man's repose, night hushes every noise. It indeed suffers a few animals, whose grim aspect might scare him, to go forth, and silently seek their food. It permits however, the animal that stands sentinel by him, to give him notice of what concerns him. But it keeps the horse, the ox, and all his domestics fast asleep around him. It disperses the birds, and sends each to his respective abode. As it comes on, it gradually hushes the winds, to secure the lord of nature's rest. It causes his repose to be revered every where: the moment of which is no sooner come, but all creatures retire, and for several hours, an universal silence reigns.

Nor yet is nature's palace wholly void of light. As some may be constrained to travel by night, several flambeaux are scattered through the firmament. But these, though they prevent total darkness, yield only a gentle light. Nor ought those who then wake to be supplied with such a light, as would interrupt the repose of others.

But it is not by its darkness only, that night is useful to us. Its coolness likewise is of use: and

this increasing the spring of the air, makes it capable of working with greater activity, and giving new vigour both to the dry plants and the enfeebled animals. It is to preserve this cool, that the moon reflecting the light of the sun, gives it without any sensible heat. In vain do we collect her rays by the strongest burning glass. An admirable caution of the Divine Artificer, who has reserved for the night season, a light strong enough to remove darkness, yet too weak to alter the coolness of the air.

When man is inclined to have the benefit of this, he sees no more the prospects of the day; but night, in her turn, favours him with another, that has charms to itself.

We cannot doubt but these immense globes of fire, which enlighten our night, have all their peculiar appointments, which answers, in God's purposes, the magnificence of their appearance. But who shall presume to explain, what the Almighty has thought fit to conceal? The small glimpses which a few are permitted to have, being quite unknown to the bulk of mankind. It is not in the particular destination of each star, nor in the general harmony of all, that we are to look for the means of instructing man, or regulating his affections. But yet what we do see, and know concerning them, is matter for the deepest admiration. We see innumerable fires hung up in the magnificent ceiling of our abode: and the dark azure which serves them as a ground, still heightens their beauty and brightness. But their rays are dispersed through spaces so immense, that when they come to us, they are quite destitute

tute of heat. Thus by the Creator's providence we enjoy the sight of a multitude of fiery globes, without any danger of destroying the coolness of our night, or the quiet of our repose.

The sum of what has been said, with some farther improvements, I add in the words of Mr. Hervey.

“ The earth is, in fact, a round body, though in some parts raised into hills, or sunk into valleys, in others spread out into wide and immeasurable plains. For the loftiest mountains bear no more proportion to the whole surface of the ball, than a particle of dust on the astronomers globe, bears to its whole circumference. We may fancy that it has deep foundations, and rests on some solid basis. But it is pendent in the wide transparent ether, without any visible support either from above or beneath. It may seem to remain still and motionless: but it is continually *sailing* through the depths of the sky, and in the space of twelve months finishes the mighty voyage. This periodical rotation produces the seasons, and completes the year. And all the time it proceeds in its annual circle, it *spins* upon its own center, and turns its sides alternately to the great fountain of light. By this means the day dawns in one hemisphere, while the night succeeds in the other. Without this expedient, one part of its regions, would during half the great revolution, be scorched with excessive heat, and languish under an uninterrupted glare: while the other would be frozen to ice, and buried under dismal and destructive darkness.

“ The earth in the revolution which it performs daily on its own axis, *whirls about* at the rate of above a thousand miles an hour. What an amazing force must be requisite, to protrude so vast a globe, and wheel it on, loaded with huge rocks and mountains, with such a prodigious degree of rapidity !

“ Meantime the sun, which seems to perform its daily stages, is *fixed* and *immoveable*. It is the great axle of heaven, about which the earth and many larger orbs wheel their stated courses. And small as it seems, it is far larger than the earth: Sir Isaac Newton supposes, 900,000 times. Are we ready to cry out, How mighty is the Being who kindled such a prodigious fire ? And keeps alive from age to age, such an enormous mass of flame ? And yet this sun, with all its attendant planets, are but a very small part of that grand machine, the universe. Every star is really a vast globe, like the sun in size and in glory. Nay, every star, as some suppose, is not barely a world, but the center of a magnificent system ; has a retinue of worlds enlightened by its beams, and revolving round its orb : all which are lost to our sight, in immeasurable wilds of ether.†

“ But could you soar farther yet, could you wing your way to the highest apparent star, you would there see other skies expanded, another sun distributing his beams by day, with other stars, that gild the horrors of the alternate night : and other, perhaps nobler, systems established, through the boundless dimensions of space. Nor does the dominion of the great Sovereign, terminate even
here

† All this is spoken on the Newtonian Hypothesis.

here. Even at the end of this vast tour, you would find yourself advanced no farther than the *suburbs* of creation : arrived only at the *frontiers* of the great Jehovah's kingdom.

“ Think on this. When innumerable bodies, many of them more than an hundred thousand miles in diameter, are set in *motion* : when the *orbits* in which they move are extended, to hundreds of millions of miles : when each has a *distinct* and *separate* sphere, for finishing his vast circuit : when none is *cramped*, but each *freely expatiates* in his unbounded career : when every one is so immensely distant from the others that they appear each to other, as only so many spots of light : how astonishing is the expanse which yields room for them all, and their widely diffused operations ! To what lengths did the Almighty Builder stretch his line, when he marked out the stupendous platform ! I wonder at such an immeasurable extent : my thoughts are lost in this abyss of space.

“ To go one step farther still : when I contemplate those ample and amazing structures, erected in endless magnificence, over all the ethereal plains : when I look on them as so many repositories of light, or fruitful abodes of life : when I remember there are orbs vastly more remote, than those which appear to our unaided sight : when I stretch my thoughts to the innumerable orders of beings, which inhabit all those spacious systems, from the highest seraph to the puny nations that tinge the plumb with blue, or mantle the standing pool with green. How various are the links in this immense chain, the gradations in

this universal scale of existence ! Yet all these are the work of God's hand, and are full of his presence !

“ He rounded in his palm those dreadfully large globes, which are pendulous in the vault of heaven. He kindled those astonishingly bright fires, which fill the firmament with a flood of glory. By him they are suspended in fluid ether, and never can be shaken : by him they dispense a perpetual tide of beams, and never are exhausted. He formed that exquisitely fine collection of tubes, that unknown multiplicity of subtle springs, which organize and actuate the frame of the minutest insect. He bids the crimson current roll, the vital movements play, and joins together a world of wonders, even in an *animated point*. For there are living creatures abundantly smaller than a mite. Mr. Bradly mentions some, which by computation he found to be a thousand times less than the least *visible* grain of sand : at the same time he declares, that this was a bulky being, compared to others discovered by Mr. Lewenhoeck. If then we consider the *several limbs*, which composed such an organized particle : the different *springs* which actuate those limbs ; the flow of *spirits* which put those springs in motion ; the various *fluids* which circulate ; the different *secretions* which must necessarily be performed ; together with the proportionable minuteness of the solids, before they arrive at their full growth : we shall see the utmost reason to own, that the Creator is greatly glorious even in his smallest works.

“ To conclude this head. If the stars are magazines of *fire*, and immense reservoirs of *light*,
undoubtedly

undoubtedly they have some grand uses, suited to the magnificence of their nature. To determine what uses, is not possible, in our present state of distance and ignorance. This however is clear, they are disposed in such a manner, as is most pleasing, and serviceable to mankind. They are not placed at such an infinite remove, as to lie beyond our sight: neither are they brought so near to our abode, as to annoy us with their beams."

12. A year or two after the preceding volumes were published, the little sketch of Astronomy therein given, (or rather my doubts concerning it) was warmly attacked in the London Magazine. The substance of those objections, and of my answer, I have here subjoined.

S I R,

I am obliged to you for your queries and remarks; and so I shall be to any who will point out any thing wherein they think I have been mistaken. It would not be strange, if there should be many mistakes in the "Compendium of Natural Philosophy:" as Philosophy is what for many years I have only looked into at leisure hours. Accordingly in the preface of that treatise I said, "I am thoroughly sensible, there are many, who have more ability, as well as leisure, for such a work than me. But as none of them undertakes it, I have myself made some little attempt in the following volumes."

Q. 1. "You say, The sun is *supposed* to be abundantly larger than the earth? Is it not *demonstrable*, that he is so."

O 5

I do

I do not know whether it is, or no.

Q. 2. " Why do you say, the moon is *supposed* to be forty-five times smaller than the earth, when the moon's bulk is nicely known ?"

It is not *known* by me, nor, I doubt, by any man else.

Q. 3. " You say, Jupiter is supposed to be twenty-five times larger than the earth: and in the next page, that his diameter is supposed to be 130,655 miles. If so, is he not 4096 times larger than the earth ?"

Undoubtedly. But I do not undertake to defend either one supposition or the other.

Remark 1. " You say, p. 148. Even with respect to the distance of the sun, it is wisest to confess our ignorance, and to acknowledge we have nothing to rest upon here, but mere uncertain conjecture."

I did not say this of the distance of the sun in particular. My words, p. 146 are, " With regard to their *distance* from the earth, (the distance of all the bodies in the solar system) there is such an immense difference in the calculations of Astronomers, even with respect to the distance of the sun—that it is wisest to confess our ignorance," namely, with regard to *their* distance.

To prove that we are not ignorant hereof, you say, " The knowledge of the sun's distance depends on finding its parallax, or the angle that the semi-diameter of the earth appears under at the sun, which angle is so very minute, that an error of but a single second, will give the distance
very

very considerably greater or less than the true distance." It will: and therefore I doubt, whether the distance of any heavenly body can ever be known by this means.

" But Dr. Keil says, we are assured by various methods made use of to observe the sun's parallax, that his distance from us is more than twenty-eight millions of miles." He may be assured: but I am not. "He says farther, two eminent astronomers have since determined the sun's distance to be about seventy six millions of miles: now if the least distance possible is *absolutely determined*, how can it be wisest to confess our ignorance?" If it be—But I doubt, it cannot be determined at all: at least, not by the sun's parallax: "seeing this is so very minute that an error of a single second will give the distance very considerably greater or less than the true."

R. 2. In p. 143, you tell us. — The whole paragraph runs thus. " It is now almost universally supposed, that the moon is just like the earth, having mountains and valleys, seas with islands, peninsulas and promontories, with a changeable atmosphere, wherein vapours and exhalations rise and fall. And hence it is generally inferred, that she is inhabited like the earth, and by parity of reason, that all the other planets as well as the earth and moon, have their respective inhabitants." [I take this to be the very strength of the cause. It was this consideration chiefly, which induced me to think for many years, that all the planets were inhabited.] " But after all comes the celebrated Mr. Huygens, and brings strong reasons why the moon is not, and cannot be inhabited at all, nor any secondary planet whatever. Then"

(if the first supposition sinks, on which all the rest are built) "I doubt we shall never prove that the primary are. And so the whole hypothesis, of innumerable suns and worlds moving round them, vanishes into air."

In order to prove, that there are innumerable suns, you say, 1. "It is found by observations on the parallax of the earth's orbit, that a fixed star is ten thousand times farther from the sun than we are."

"I can build nothing on these observations, till parallaxes can be taken with greater certainty than they are at present. Therefore I still want proof, that any one fixed star is one thousand times farther from the sun than we are."

2. "They are fiery bodies." I suppose they are. But this cannot be proved from their distance, till that distance itself is proved.

3. "It is demonstrable, that Sirius is as big as the sun."

Demonstrate it who can.

4. "Seeing the fixed stars are not much less than the sun, they are to be esteemed so many suns."

Not much less! How is this proved? To argue from the distance, is to prove *ignotum per aque ignotum*.

"You see, Sir, the hypothesis of innumerable suns, is so far from vanishing into air, that it is *almost altogether* founded on demonstration."

Indeed I do not see one tittle of demonstration yet from the beginning to the end.

In

In order to prove that the planets are inhabited, you say, 1. "The earth is spherical, opaque, enlightened by the sun, casting a shadow opposite thereto, and revolving round it, in a time exactly proportioned to its distance. The other planets resemble the earth in all these particulars. Therefore they likewise are inhabited." I cannot allow the consequence.

2. "The earth has a regular succession of day and night, summer and winter. So probably have all the planets. Therefore they are inhabited." I am not sure of the antecedent. But however that be, I deny the consequence.

3. "Jupiter and Saturn are much bigger than the earth." Does this prove that they are inhabited?

4. "The earth has a moon, Jupiter has four, Saturn five, each of them larger than ours. They eclipse their respective planets, and are eclipsed by them."

All this does not prove that they are inhabited.

5. "Saturn's ring reflects the light of the sun upon him."

I am not sure of that. And till the fact is ascertained, no certain inference can be drawn from it.

6. "But is it probable God should have created planets like our own, and furnished them with such an amazing apparatus, and yet have placed no inhabitants therein."

Of their apparatus I know nothing: however if all you assert be the *probability* of their being inhabited, I contend not.

7. "They

7. " They who affirm, that God created those great bodies, the fixed stars, only to give us a small dim light, must have a very mean opinion of the Divine Wisdom."

I do not affirm this, neither can I tell, for what other ends he created them: he that created them knows. But I have so high an opinion of the Divine Wisdom, that I believe no child of man can fathom it. It is our wisdom to be very wary how we pronounce concerning things which we have not seen.

R. 10. " Suppose some intelligent beings in one of the planets, who were

Slaves to no sect, who sought no private road,

But look'd thro' nature up to nature's God :

viewed the earth from thence, they would argue, it must be inhabited, as we argue that the other planets are. But the superstitious would oppose this doctrine, and call it mere uncertain conjecture."

I see no argument in this: but perhaps I do not understand it. Are you applauding the supposed inhabitants of Venus, for not being *slaves* to the *christian sect*? Otherwise, what has superstition to do in the case? Why is this dragged in by the head and shoulders? If there be superstition here, it is on *your* side, who believe because you *will* believe: who assent to what you have no evidence for, and maintain what you cannot prove. At present you are the *volunteer* in faith: you swallow what choaks my belief.

R. II. " You quote Dr. Rogers," — But I do not undertake to defend his hypothesis, or any other. " Our best observers could never find the

the parallax of the sun to be above eleven seconds." But I cannot depend on their observations: especially when I find one of the chief of them, in computing the distance of the sun, to stride from twenty-eight millions of miles, to seventy-six: near fifty millions of miles at once! After this let any impartial man judge what stress is to be laid on parallaxes!

" But Dr. Rogers supposes the parallax of the sun to be five minutes, which others cannot find to be above eleven seconds. Why Doctor, if this be true," (namely, that the parallax which was lately but eleven seconds, is now increased to five minutes) " the earth has *approximated* thirty times *nearer*" (a little harmless tautology) " to the sun." That is, if both the computation of Mr. Keil, and that of Doctor Rogers be true! But whoever supposed this? If the one be true, the other is undoubtedly false.

" To conclude. Since there is no arguing against facts, and since the sun's parallax is found not to exceed eleven seconds, ought you not to give up that hypothesis as absurd and ridiculous?"

Yes, as soon as any of those facts appear: till then I neither espouse nor give it up. But I still look upon it as extremely ingenious, and full as probable as any other.

Before I conclude, permit me, Sir, to give you one piece of advice. Be not so *positive*: especially with regard to things which are neither easy nor necessary to be determined. I ground this advice on my own experience. When I was young I was *sure* of every thing. In a few years, having been mistaken a thousand times, I was not half so sure of most things as before. At present I am hardly sure of any thing, but what God has revealed to man.

Upon

Upon the whole, an ingenious man may easily flourish on this head. How much more glorious it is for the great God to have created innumerable worlds, than this little globe only! But after all, I would ask one plain question. Suppose there are more worlds than there are sands on the sea-shore? Is not the universe finite still? It must be, unless it be God. And if it be finite, it can still bear no proportion to him that is infinite: no more than this ball of earth does. How large so ever it be, still compared to him it is as nothing, as the small dust of the balance. Do you ask then what is this spot to the great God? Why, as much as millions of systems. *Great* and *little* have place, with regard to us: but before him they vanish away. Inlarge the bounds of creation as much as you please, still it is but a drop to the Creator.

And still the power of his Almighty hand,
Can form another world from every sand!

Yet were this done, there would be no more proportion between the world and its Creator, than there is now!

It will easily be observed that I do not *deny*, but only *doubt* of the present system of astronomy. But the ingenious Mr. Kennedy goes much farther in his *Astronomical Chronology*. I beg leave to present the impartial searchers after truth, with a short extract from it.

“ Although many persons of great abilities have thought sacred chronology worthy their most diligent researches, yet they have all failed in the main point. They have taken it for granted, that the scriptural computations are quite *unastromical*.

nomical. The title of *The World's Chronology*, has been fixed to very different collections of years, without looking for any astronomical æra, to support the title. This is the first attempt of that kind which has been made.

“ I have largely proved the fundamental proposition of the following scheme, namely, That Moses fixes the position of the sun and moon with regard to each other at the creation. And this revealed position of the sun and moon, with respect to each other at the creation, I call the scriptural, astronomical æra.

By means of this æra we may keep even pace with the two great luminaries, from the first year of the world till now. And till now my conclusions are confirmed, by the joint attestations of the sun and moon, the two *faithful witnesses in heaven*.

“ By these it is fully proved, that time commenced at our autumnal equinox, at the fourth day of the creation, at the full-moon, or the fifteenth day of the first month of the first lunar year.

“ From the autumnal equinox at the creation to the same in 1761, have elapsed 5768 years. Indeed, Capellus supposes time to commence 2 years, Archbishop Usher four years later. But could the error of a single year be discovered in the series I have collected, all would fall to the ground.

“ Touching the common astronomy, I observe,
1. Astronomers still divide the ecliptic into 360 degrees. But how unnaturally? Three hundred and sixty degrees, and near one fourth, are undeniable more correspondent to the suns annual motion. And upon this division we can make a truer calculation, than can be made upon any other.

“ 2 The

" 2. The inequality of solar tropical years, and the inequality of the equations of natural days, are established doctrines. But whoever computes the times of equinoxes and solstices, and submits his calculations to the test of the latest and best observations, will find no room for any equations at all.

" 3. Astronomers unanimously maintain, that at the end of nineteen lunifolar years, the mean new moons, and the mean full moons happen, about an hour and a half sooner than they did at the beginning of the cycle. On the contrary, I undertake to evince, that the very reverse of this is true. I allow, that at the end of nineteen lunifolar years, the moon departs from the sun : but it departs from it, not by a retrocession westward, but by a progression eastward. That is, the mean new moons and the mean full moons fall out, not an hour and a half sooner, but almost two hours later. Therefore the doctrine of lunar anticipations has no foundation in nature.

" 4. Although the quantity of a *solar tropical year* is a conclusion in astronomy, yet such an unhappy fatality has attended this research, for almost two thousand years past, that whoever examines the vast variety of opinions, must see nothing has yet been determined with certainty. So that instead of a precise and established definition, he finds little more than this general account, that the quantity of the natural year has been long and much sought after, but with small success : so that it seems at this day to remain among the yet undiscovered secrets of nature.

" Indeed

" Indeed to know this with all exactness, one would think no more is needful than to examine the tables of observations. Let us then examine that made by Tycho Brahe, in Queen Elizabeth's time, and that by Doctor Bradley an hundred and seventy years after. But in Tycho's table of twelve terminations, seven of them differ a minute from the other five. And this difference perplexes the conclusion, and leaves it in a state of uncertainty. Proceed we then to Dr. Bradley's tables. But these leave a latitude of twenty-one minutes. Thus we see how imperfect the knowledge even of the solar tropical year still is, and that no true judgment can be formed concerning it, either from observation or tabular calculation.

" 5. It requires no small skill, even to determine the distances of the sun's four stations, at the vernal and autumnal equinox, and the summer and winter solstice. Nay, it is a question whether this determination likewise must not still be reckoned among the secrets of nature.

" And if we would correct the tables of these by Dr. Keil's Rule, yet this very correction leaves us four different measures according to the majority of Tycho Brahe's corrections, according to Sir Isaac Newton's, Dr. Halley's, and Dr. Bradley's corrections. So that still we come to no certainty, even as to the solar stations. We are at a stand, like a traveller, who arriving at a place where four ways meet, is at a full stop, for want of a clear distinction, which of them to take.

" 6. The greatest astronomers are not agreed, even as to the length of a natural day.

Mr.

" Mr. Ferguson observes,

" The fixed stars appear to go round the earth in twenty-three hours, fifty-six minutes and four seconds, and the sun in twenty-four hours. Therefore in three hundred and sixty-five days, measured by the returns of the sun to the meridian, there are three hundred and sixty-six days as measured by the stars returning to it. The former are called Solar days, the latter Sidereal. But whoever will compare this with the determinations of Dr. Keil, will find them flatly contradictory to each other. And the farther he examines the most celebrated writings, the more deeply he will be convinced, that neither the precise length of a sidereal day, nor the complement of the solar, has yet been determined with certainty."

Whoever desires to see these propositions proved at large may have recourse to the book itself. But if these things are so, what becomes of the whole fabric of even Newtonian astronomy? How can I depend on the calculations of those concerning the motions of the heavens, who know so little about the earth? What instruction can they give me concerning other systems, who are so unskilled with regard to our own? Why does not some eminent astronomer undertake this daring man, who so violently attacks the very foundation of their building? For if his remarks are just, sensible men will be inclined to think, that after all the parade of mathematical demonstration, there is little more certainty in astronomy itself, than even in judicial astrology!

And how just are the great Mr. Boyle's remarks, upon the whole of Natural Philosophy?
 " The most, says he, even of modern virtuosi,
 fancy

fancy more certainty in their physical theories than a critical examiner will find. I will touch only on two subjects, which we commonly think are, and which surely ought to be, most thoroughly understood: I mean, the nature of the Body in General, and the nature of Sensation. As to the first, since we turn ourselves no way, but we are invironed by corporeal substances, one would think, an object that so many ways affects our Senses, should be perfectly known to us. And yet the notion of the Body in general, or what it is that discriminates bodies from other substances, is not by any means agreed even among the modern philosophers. And indeed, no account of it, which has yet been given, will extricate us out of the difficulties of that no less perplexed than famous dispute, "Of the Composition of Bodies." But the difficulties attending this, will, till they are removed, spread a thick night over the notion of Bodies in general. For either a corporeal substance is divisible into extended parts, and each of these divisible into other parts smaller and smaller, *ad infinitum*, or this division must stop somewhere. But there are inconveniencies, not to say absurdities urged against either of these suppositions. The objections on both side are so strong that the most sensible and candid men, after having tired themselves and their readers with striving to solve them, have at length owned them to be insoluble.

"But though we do not understand the nature of Bodys in general, must we not perfectly understand what passes within ourselves, in reference to the particular bodies we daily see, and hear, and smell, and taste, and touch? These we know by our senses: but how little do we know of the manner

manner wherein our senses inform us of any thing ? Sensation we allow is not performed by the organ, but by the mind perceiving the motion produced in the organ. Ask then a philosopher how the soul comes to be wrought on, and that in such various manners, by those external bodies, which are the objects of our senses ? He will tell you, that by the impressions on the organs, they variously move the nervous fibres, wherewith those parts are endowed, by which the motion is propagated to the brain : where these motions being perceived by the soul, become Sensations, through the intimate union of the soul with the body. But give me leave to take notice that this union of an incorporeal with a corporeal substance, is a thing so difficult to comprehend, that the profoundest secrets of theology, not to say the incarnation itself, are not more abstruse than this. For how can we conceive that a substance purely immaterial, should be united without any medium (and in this case there can be none) with a body that cannot possibly lay hold on it, and which it can pervade, and fly away from at pleasure ? And it is almost as difficult to conceive, how any part of the body, without excepting the animal spirits of the brain (for these are as truly corporeal as the other parts) can make impression on a substance perfectly incorporeal, and which is not affected by the motions of any parts but the nerves. Nor is it a small difficulty to conceive how a finite spirit, can either move, or (which is much the same thing) regulate and determine the motion of the body.

“ And suppose the soul in the brain does perceive the different motions communicated to the senses, yet this, though it may give some account
of

of Sensation in general, does not give us any satisfactory reasons of particular sensations. For if I demand, for instance, when I look on a bell that is ringing, such a motion, in the brain produces in the mind the perception of seeing and not hearing, and another motion coming from the same bell at the same time, produces in the mind, the perception of hearing, not seeing: what can be answered, but that such is the good pleasure of the Author of nature? And if we ask about the differing objects of any one sense, as, Why the light reflected from snow, produces a sensation of whiteness rather than redness? Why Castor produces a stink, and not a perfume? Why sweet things generally please, and bitter disgust us? Nay, why a little of some objects (suppose fire) will give pleasure, a little more of them give pain? To these and a thousand other questions of the same kind, it can only be answered, Such is the nature of man. So plain is it, that we are yet to seek both for the definition of a corporeal substance, and for a satisfactory account of the manner of our own sensations. Yet without the true notion of a body, we cannot understand the object of physics in general: and without knowing the nature of the sensation, we are ignorant of that, from which we derive almost all that we know of any body in particular.

“And as our philosophical knowledge is not very deep, not reaching with any certainty to the bottom of the most obvious things, nor penetrating to their inmost nature: so it is not very wide, not being able to give us with any clearness or particularity, an account either of the celestial parts, of the world, or of the deeply subterraneous parts of which the superficial part is but a small, not to say contemptible,

contemptible portion. As to the very globe we inhabit, (not to mention how many plants and minerals we are wholly ignorant of, and how many others we are but slenderly acquainted with) the objects about which our enquiries and experiments are conversant all belong to the superficial parts of the globe, of which the earth known to us is but the crust. But what the internal part of it is, we no more know, than what is the substance of the remotest stars. Even among the moderns some think the internal part of it, is pure elementary earth. Others imagine it to be fire, the receptacle of natural or hellish flames. Others will have the earth to be a solid magnet; while others believe it was once a fixed star: and that though it is now degenerated into a planet, yet its internal parts are of the same nature as before: the change proceeding only from thick spots that cover it, (like those frequently observed upon the sun) by the condensation whereof the firm earth, which we inhabit, was formed. And it is difficult to demonstrate the falshood, as the truth, of each of these jarring opinions. For whereas it is at least three thousand five hundred miles to the center of the earth, it does not appear, that men have been able to penetrate towards it either by land or by sea, above one, or two miles at the most, and that not in above three or four places. So that as yet we have not penetrated any thing deep upon the husk, without at all reaching the kernel of the globe. And what is this globe, of which itself we know so little, to those vast globes of which we know much less? For though the former astronomers give us their distances and magnitudes as exactly as if they had measured them, yet the latter mathematicians give us reason
to

to doubt of what those have delivered. For since we can observe no parallax in the fixed stars, (nor perhaps in the highest planets) we must still be to seek for a method to measure the distance of those bodies. And not only the Copernicans make it many hundred thousand miles greater than the Ptolemeans, but Ricciolus makes it vastly greater than the Copernicans themselves. Nor can we wonder at these huge discrepancies (though some amount to many millions of miles) when we consider that Astronomers do not measure the distance of the fixed stars, by their instruments, but each accommodates the distance of them to his peculiar hypothesis. From this uncertainty of the distance of the fixed stars, it is easily inferred, that we are not sure of their bulk: no, not even in reference to one another; since it is doubtful whether the different sizes they appear to be of, proceed from an inequality of bulk, or only from an inequality of distance. But besides these, there are divers things relating to the stars, so remote from our knowledge, that they are not even enquired into: such as these, Why the number of the stars is neither greater nor less than it is? Why so many of them are so placed, as not to be visible to the naked eye? Why of the visible ones, so many are in one part of the sky, and so few in others? Why they are not placed in some order, but scattered over the sky, as if it were by chance? Many questions might be added, as concerning the stars, so concerning the interstellar parts: as whether they are empty, save where they are pervaded by light, or filled with ethereal matter? So that our knowledge is much short of what is generally thought. For the earth being but a point, compared to the orb of the sun: which orb itself is but a point in

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respect of the firmament: of how little extent must our knowledge be, which leaves us totally ignorant of so many things touching the vast bodies which are above us, and penetrates so little a way into the earth beneath us, that it seems confined to but a small share of a superficial part of a physical point."

Perhaps it will be acceptable to calm, dispassionate men, if I add another extract from a very sensible writer, containing a few short observations, on the whole present system of Philosophy.

1. "The first axiom in the present philosophy is, That all *Matter is indifferent to Motion or Rest*. But do we not here stumble at the threshold? laying as a fundamental truth, what is manifestly false? For Motion and Rest are such opposites, that implies a contradiction to suppose an equal disposition to either, inherent in the same body. The one is a *positive*, which necessarily implies power, the other a mere *negative*, which implies no power in any direction.

2. Matter containing in itself no power of any kind, can give no *resistance* to any impression upon it; neither can it of itself *continue* to exert the effects of that impression. Therefore the second axiom, or rather the phænomena, from which it is deduced, must arise, not from matter in itself, but from the relation which all matter bears to the universal system of nature.

3. The third axiom, concerning *re-action* is as exceptionable as the two former. For it may easily be shewn, that the Re-action of matter depends

pende entirely on gravity. If gravity were subtracted, there is no proof or reason to suppose, that bodies would exert either Resistance or Reaction. All these axioms therefore, instead of being absolute laws, are mere phænomena depending on other causes, which causes it is incumbent upon the philosopher to look for.

4. The *projectile power* never can balance that of gravitation, so as to maintain the motion of the planets. It can never recover its force when it is resisted, whereas gravity can. Therefore the constant bending of its direction, which must be equal to a constant proportionable resistance, must uniformly and perpetually weaken its power, and strengthen that of gravitation; so that the direction of motion must necessarily sink more and more, and at last fall wholly into the direction of gravitation. It follows that no power acting upon an orb which gravitates towards its center of motion, can possibly maintain its projectile motion, in the direction of a circle.

5. Even on supposition that projection and gravitation equally retained their propensity to motion though resisted, yet those powers could not move the planets in ellipses, because in the same proportion as the one prevailed over the other, in the same proportion it must alter the tendency of motion towards its own direction. And none can explain how, when a quantity of motion and also of inclination is gained by gravitation over projection, the orb will, while these remain unchanged, leave at any point the direction of the moving power that prevails, and recede into the direction of the weaker power, or *contra*.

6. Again. From the proportions of the forces required between gravitation and projection, in order to move the orbs in circles, it is evident that these two powers cannot be the cause of their motions. For by comparing the forces of these it appears, that the force of gravitation is not such in proportion to that of projection, as to bend the direction of the projected body sensibly from the right line.

7. The motion of the *moon* along with the earth, cannot be owing to her gravitating towards it, nor to a projection impressed upon her, in common with the earth: because she has a projection of her own round the earth. And she cannot be so projected as to move in two different orbits at one and the same time, by the *vis inertiae* continuing one projectile motion round the sun, and another round the earth. Therefore the motion of this, and by a parity of reason, that of all the secondary planets, must be guided every moment either by mechanism or by a spiritual power.

Indeed Sir Isaac thought these powers might arise from a subtle, etherial medium, diffused through the whole universe: but this is only retreating a step farther in the dark. For it comes to one, whether the cause of attraction be assigned to grosser bodies themselves, or to the impulse of a medium that penetrates them. If the powers of that supposed medium are unmechanical, they must be spiritual. And seeing the medium is only supposed, it is more natural to assign these unmechanical powers, to bodies which we know disposed to these motions, than to supposed bodies, which we know nothing of.

Farther. If Sir Isaac supposes such a medium for maintaining attraction, gravitation, and elasticity,
how

how came he not to suppose that the same is concerned, in supporting his axioms or laws of motion? For the knot does not lie in gravitation or attraction, or any *particular kind* of motion, but in finding powers to produce and maintain *motion in general*. If these are mechanical, it is easy to suppose, though we should never be able to explain in what manner that the contriver has adjusted the mechanism to produce all the motion observable in the creatures. But if they are unmechanical laws, properties, or whatever we may call them, there is no occasion for supposing any cause of gravitation, or for taking it amiss to have it called an occult quality, unknown virtue, charm, law, or any word we have no meaning to.

8. This unmechanical philosophy has a bad influence in obstructing our advancement in the knowledge of nature. For how can enquiries into the powers of nature be carried on to any degree of perfection, under the direction of a system which muffles our eyes with unmechanical laws of matter, suppose the basis of mechanism, instead of examining whether these themselves are not the production of mechanism? Such are the indifference of matter to continue itself either in rest or motion: re-action equal to action: the resistance of matter to a change of state: gravitation, attraction, repulsion, elasticity: pressure of fluids in all directions: a fluid with no cohesion of parts, moving in diverging lines; whose parts are possessed of different degrees of attractability by other bodies contrary to that law which makes gravitation simply as the quantities of matter: a fluid possessed of alternate fits of attraction and repulsion! How weak is it, to make these the basis of mechanism, rather than the result of it?

9. Let us now examine these matters more closely. In the present philosophy, *Space* is always considered in the first place; because without admitting space void of matter, the whole system falls to the ground.

This same infinite Space is the most wonderful thing within the whole range of being. It is neither God nor his creature, and yet is inseparable from the being either of God, or of any thing he can create. It is infinite both in its extension and in its duration. It is immoveable and indivisible. If a compleat definition of it were put into a lady's pocket-book, she would guess it to be an enigma for *nothing*: and would be astonished to hear, that it is the quintessence of a most metaphysical and most subtle argument maintained by a most celebrated divine and philosopher.

The only positive idea applied to space is *Extension*. But we can apply no idea to any subject, which the subject itself does not impress. Matter forces upon our senses the idea of its extension. But how can we invest with this, a subject which never excited any idea in us, and consequently has no existence *to us*? Space is only one of the ideas excited by matter, and by the mind abstracted from its subject, just as we can image a colour to ourselves, without connecting any particular subject with it. A little more of the same metaphysics, which can prove that *nothing* is extended, will prove that space is purple. But why should I say purple? Space is of all colours, if light is reflected by a vacuum. It is an ingenious contrivance, to render *nothing* a subject of conception, by dressing it in a suit of cloaths borrowed from *something*.

To illustrate the doctrine of Space, a common experiment shews, that by an image formed in
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the air, at a certain distance between a concave glass and any person looking into it, extension becomes an object of sense, where there is neither solidity nor any sensible resistance. But this does not prove that an image is formed in empty Space, or where there is no matter: it rather proves that these spaces which they call empty, are full of matter. For as the senses can be affected only by matter, they infallibly determine where matter is. So that we are as sure there is matter where we see any thing, though we cannot feel it, as that it is there, where we feel, though we cannot see it.

10. Let us now more attentively consider the first supposed law of motion, *Matter is indifferent to continue in Motion or in Rest.*

Rest and Motion are the two greatest opposites in nature, as opposite as matter and nothing. The mind therefore cannot be struck with a more palpable contradiction, by affirming that a body is equally disposed to hardness and softness at the same time, than by saying it is equally disposed to rest and motion.

Motion is a positive thing, which implies action, power, or force, wherever it acts. Rest is a mere negative, a state wherein body is divested of all these. It exerts no power; it acts or presses, neither backwards nor forwards, neither up nor down. Now the same body cannot be indifferent to the exerting of power and to the exerting of none at the same time.

Again. It is impossible that rest and motion can be equally indifferent to matter. When matter was created, should we suppose the Creator

to say, "Let it be," *without* determining in which of these states it should commence being; yet it is impossible it could begin to be, both moving and resting. It could assume only one of these conditions, and must have remained therein for ever, unless some farther divine energy had given it a new determination. Now in which ever of these matter began to exist, that must be called its *Natural State*. And every alteration of that state must be the effect of some power superinduced upon it, which must cease when the cause ceases.

Again. Matter may exist in rest: but no *living* matter. All life in nature, whether mineral, vegetable, or animal, depends upon motion and activity. Therefore motion seems to be not the natural state of matter, but superadded thereto, and constantly supported, in order to constitute life, variety, and mutability. Now all know, material motion proceeds upon, and is regulated by mechanical laws. And does not motion uniformly conducted by the laws of mechanism, imply a constant mechanical cause? This mechanical system is traceable in most cases, even in the most subtle and elaborate works of nature, such as plants and animals. And may not the same heavens which influence every thing on earth, rule the motions of the earth itself; and impress all matter with these general tendencies, which are the basis of all human mechanics?

11. Proceed we to what is called *the second law of motion*.

We can have no idea of power, but that it is matter in motion, or endeavouring to act. We cannot connect the idea of power with matter at rest.

rest, unless that rest be the effect of power fixing it in its place, which we may term *mechanical* power. This rest, being an effect of power, will exert a resistance to motion, when it is pressed upon. But otherwise, matter can have no such power in itself, can exert none; because power consists in Motion, or a nifus to it. Therefore matter resting *unmechanically* can have no nifus of any kind. An unmechanical nifus in matter to rest, is in other words an active power exerted by it to do nothing.

The states then of Motion or rest being the result of absolute passiveness in matter, and the effect of no positive nifus, an unmechanical matter can exert no resistance to change the state: and of consequence an atom would have as much power to move a planet, as a planet to move an atom.

An action or tendency to action is plainly implied in a nifus to any state. And as a nifus to passiveness is a contradiction in terms, it follows, that the properties of power or motion, cannot be considered in matter taken abstractedly, but as composed into a system. Therefore, though it must be allowed, that the changes of state in matter are proportioned to the powers that produce them, yet it is impossible to conceive, that the power shall continue in the body acted upon, after the exterior power ceases to act upon it.

12. The *third* supposed *Law of Motion* is this, When matter is put into Motion, it communicates as much resistance toward stopping the motion of the body that moves it, as it receives motion from it.

Philosophers never had it in their power to make the experiments on which this law is grounded, upon any bodies but such as were under the influence of gravitation. And if this axiom can be proved to depend upon gravitation, it must cease to be an axiom, as being only an accident depending upon another acknowledged cause.

Resistance or re-action must be produced wherever matter in motion encounters matter moving or tending to move in an opposite or a different direction. Now all bodies tend or gravitate toward the earth. Therefore this tendency must re-act or resist according to its quantity, every power applied to move a gravitating body in any other direction.

We have no way to estimate the quantity of matter contained in any bodies, but the quantity of their gravitation. Hence we must necessarily infer, that the law of re-action, is not according to the quantity of matter in particular detached parcels thereof, but according to the degree of their gravitation. For were the gravity of a body but the half of what it is now, that body would re-act but half as much as it does; and of course, were all its gravitation to cease, it would not re-act at all.

Again. It is supposed, gravitation is twenty-three times greater on the surface of the sun than on the surface of the earth. Hence a body which weighs one pound here, would there weigh three and twenty. Consequently without any addition of matter, it would re-act twenty-three times more than it does here. Therefore this re-action, supposed an absolute law of matter, is only a circumstance depending on the relative law of gravitation.

13. Come we now to the doctrine of *Centripetal* and *Centrifugal* forces.

In another age it will be matter of universal wonder, that one of the most profound mathematicians in the world should assume two powers for circulating the planets, and even calculate the quantities of matter therein, from the proportions wherein they must act in producing and maintaining the circuits of the moving stars: while it is demonstrable to common sense, from the admitted nature of these two powers, that it is absolutely impossible they can support one single rotation of an orb.

Gravitation is allowed by all to be a constant power in bodies, which cannot be altered but by change of distance. It cannot be suspended; for though its effect may be resisted, yet its tendency thereto is invariable. It is therefore a proper undestroyable power, uninterruptedly acting in and upon bodies.

The laws assigned to *Projection* are just the reverse. When any proportion of the quantity of projectile motion is destroyed, either by direct opposition, or by change of its direction, it exerts no nifus to recover its first quantity of motion. Consequently as long as any power, such as that of gravitation, is bending the direction of projection, it is a continued resistance of the power of Projection, which is continually diminished thereby. And as it has no tendency to recover this, the smallest continued resistance will at last quite exhaust its power, though originally ever so great. Thus every projectile on the earth, however great the projecting force may be at setting out, is continually retarded till it rests in the direction of a parabolic curve.

Sir Isaac seems not to have reflected on this circumstance of Gravitation and Projection, that the one retains its whole tendency to motion, whether it be retarded or stopped, while the other always loses as much power as it meets with opposition. Neither in balancing these powers, does he seem to have reflected on that obvious truth, That every alteration in the direction of a moving projectile, destroys so much of its motion, which cannot be repaired, but by a continued action of the first moving cause.

Philosophers illustrate the joint effect of centripetal and centrifugal force, in making bodies move in a circle, by the experiment of casting round a weight, suspended by a string in one's hand. But this illustration contains a palpable deception. For the power of the string restraining the body from flying off in a strait line, bears no analogy to a power actually drawing a moving body towards its center of motion. The string resists its flying off, but has not the least tendency to draw it nearer. And whatever is the cause of the revolution of the planets, it must be some cause which simply resists their flying off into eccentric motions. It cannot in the nature of things be one, which is uniformly drawing them into their center of motion.

But suppose both Gravitation and Projection had the same property, of still retaining their original tendency to their respective motions, however they were retarded: still it is impossible that these two powers, acting by immutable laws, can move an orb any otherwise than in a circle: whereas all the planets are allowed by philosophers themselves to move in ellipses.

These powers moving an orb in the figure of an ellipsis, must no less than four times vary the proportion

proportion of their several impulses, during every compleat revolution. The power of gravitation is uniformly gaining on that of projection, from the higher point of the ellipsis to the lower. Now (not to ask how the projectile force recovers itself, but supposing it had this property) I ask, by what law does Gravitation remit the strength it has gained, in bringing the orb from the higher point to the lower, and at that point allow Projection to recover the force it had lost, in order to carry it back to the higher point? In like manner seeing Projection has been gaining on Gravitation, all the way to that point, how comes it all at once to lose its superior force there? And how comes Gravitation immediately to preponderate, in order to bring the orb to the lower point again?

It cannot be said, that the increased velocity, which brings a planet to the lower, contributes to carry it back to the higher point. For that increased velocity was not the effect of Projection but of Gravitation. Therefore the orb can never get outward again, unless at that point, Gravitation all at once weakens its pull of the planet inwards.

There is one circumstance more, which Mathematicians ought to consider well: namely, that no figure (circle or ellipsis) can be described by Gravitation and Projection round the center of gravity, where the center of gravity shall not be found in the center of the figure. But this is contrary to all astronomical observation upon the motion of the planets, which determines their center of gravity to be always in one of the foci of their elliptical orbits.

Yet farther. In order to move any body in a circle, the moving powers must be equal, or nearly
so

so. Now the proportion of the moving powers upon one body to each other, can only be determined by the velocity of the respective motions. Indeed, the quantity of motion in different bodies must be determined by the quantity of matter moving and velocities taken together. But in one and the same body it may be determined solely by the velocity of its motions.

Equal powers then can only be determined by the equal quantities of motion they produce. But as to the powers of Gravitation and Projection, the proportion between them, as ascertained by the ablest mathematicians, is so far from being equal, that the immense disparity between them, can scarce be reduced to a calculation. Therefore it is utterly impossible that these two powers should produce the revolution of the earth.

If the sun and earth were as near each other as the earth and the moon are, and were left to the power of there mutual attraction, they would move toward each other with the same velocity as it is supposed the earth and moon do, which I think is about sixteen feet in a minute: except so far as the proportion of matter in the earth to that in the sun, differs from that of the earth to the moon. If then the earth at that distance from the sun, would gravitate toward him with the velocity of sixteen feet in a minute, and if the decrease of Gravitation, be inversely as the squares of the distances, (that is, at double distances four times less) then the earth being immensely farther from the sun than the moon is from the earth, the velocity with which the earth at her present distance from the sun would move towards him, if left to the power of attraction, must be immensely less than sixteen feet in a minute. But what is the
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the force which moves the earth sixteen feet or a thousand, to the force of that projection, which is supposed to move it at the rate of near a thousand miles in a minute?

In short, if the power of Gravitation draws the earth toward its center of gravity, with the force of sixteen feet, or sixteen hundred in a minute, while the power of projection impresses it with the force of almost a thousand miles in the same time, it is impossible for mathematics to demonstrate, that any orb hurried off by such a Projection, can ever be recalled from its eccentric motion, by such an inconceivably small and disproportionate resistance: especially as the power of Gravitation, small as it is, must be growing smaller every moment. Nor can the mathematical properties of an ellipsis, or any figure, ever prove that Gravitation, which is continually wasting and spinning out into a cobweb thread, will at any point recover a superiority to the projectile force, and grow at last a cable, massy and powerful enough to bring home the wandering star again.

14. I would add some thoughts on the motion of the *Satellites*. It is no wonder that notwithstanding all the arguments for the motion of the earth, yet the greatest part of astronomers have not pronounced it absolutely certain, but only probable in an high degree. Among the perplexities which attend this highly probable system, the doctrine of *absolute motion* is not the smallest. It is certain all the phenomena of relative motion, are the very same as if the earth were at rest. And it is not easy to conceive how this can possibly be, on the supposition of the earth's motion.

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The phænomena of bodies moving in the same direction with the absolute motion of the earth may be comprehended. That motion of bodies cross the absolute motion of the earth is also intelligible. But it is no easy matter to satisfy one's self, about the phænomena of bodies moving westward, or in an opposite direction to that of absolute motion. If we should suppose that a ball fired pointed blank west, does not really move westward, but it is only resisted by the explosion from moving so fast east as the earth goes in her absolute course; may it not be asked, What is it, that keeps the ball suspended, while the earth proceeds in her absolute motion? For the resistance given to the progressive motion of the ball, can be no resistance to its following the course of its gravity: as we have no example to explain how resistance applied horizontally will prevent a body's falling to the ground in the same time as if it was not so resisted. If the ball's absolute motion is only the force of its *vis inertiae* derived from the earth's motion, and its apparent motion in a contrary direction is only from another *vis inertiae*, derived from the explosion: what possible conception can be framed of the two opposite *vis inertiae*, acting so as to prevent a body for some time from pursuing the course of its gravity?

On the other hand, if the motion westward is *real*, it seems to imply a plain contradiction. For no body can really move eastward and westward at one and the same time.

But though the doctrine of projectiles could be reconciled with the motion of the earth, yet what shall we say of self-moving bodies? That absolute motion which all bodies are supposed to partake of, is not alledged to be maintained in them,
after

after they are separated from the earth, by any other means than their *vis inertia*, or their retaining the quantity of motion once impressed upon them. Now no body can move in a direction opposite to its *vis inertia*, till that is overcome. How is it conceivable then, that birds, for example, after they are separated from the earth, where they acquired their absolute motion, should retain it all? Certainly every reluctance of their's in an opposite direction, while on the wing, must destroy part of their absolute motion, as they cannot then have any fresh absolute motion communicated to them. This should imply a great change in the phænomena, with regard to the motion of self-moving bodies. But in fact all the phænomena are the same, as if the earth were at rest. In short, the motion which bodies have in common with the earth, is something which no re-action has any effect on. Therefore it does not, cannot depend upon the axioms of the present philosophy.

When we come to apply the theory of absolute motion to the *secondary planets*, in whatever light we consider it, it becomes a matter utterly inconceivable, nay, impossible. In the first place, we know of no absolute motion, communicated from greater to smaller bodies, but where they are so intimately connected, that gravitation at last, yea soon destroys all their projectile motion. But such is the distance of the moon from the earth, and so remote is their connexion, that her gravitation has never gained any thing upon her projectile motion.

Again. The moon, suppose her present distance from the earth to be her original one, could never by means of the weak connexion of gravitation,

tation, correspond with the projection of the earth. Suppose the moon at her present distance, and behind the earth, just in the course of the earth's projection: in this situation, suppose the moon advances toward the earth, at the rate of sixteen feet in a minute, while the earth is projected away from the moon near a thousand miles in the same time: can any one suppose, that this imperceptible motion of the moon toward the earth, would draw the moon with the force of the earth's absolute motion? This supposition is attended with the same manifest impossibilities, in whatever part of her circle the moon is considered, at the moment of projection. Suppose her in her first quadrature: then the gravitation between them and the projection of the earth lying nearly in the same direction, nothing could prevent their collision in a few hours: and till they had met, their mutual gravitation could have no effect in communicating the absolute motion of the earth to the moon. Yet supposing that the projection of the moon round the earth, commenced at the same instant with the projection of the earth, does not help: for as it is not that projection which gives the moon her absolute motion, the whole impossibility remains, yea, and is renewed every month in every supposable circumstance. For it is as impossible her absolute motion can be maintained by such means, as that it should commence by them.

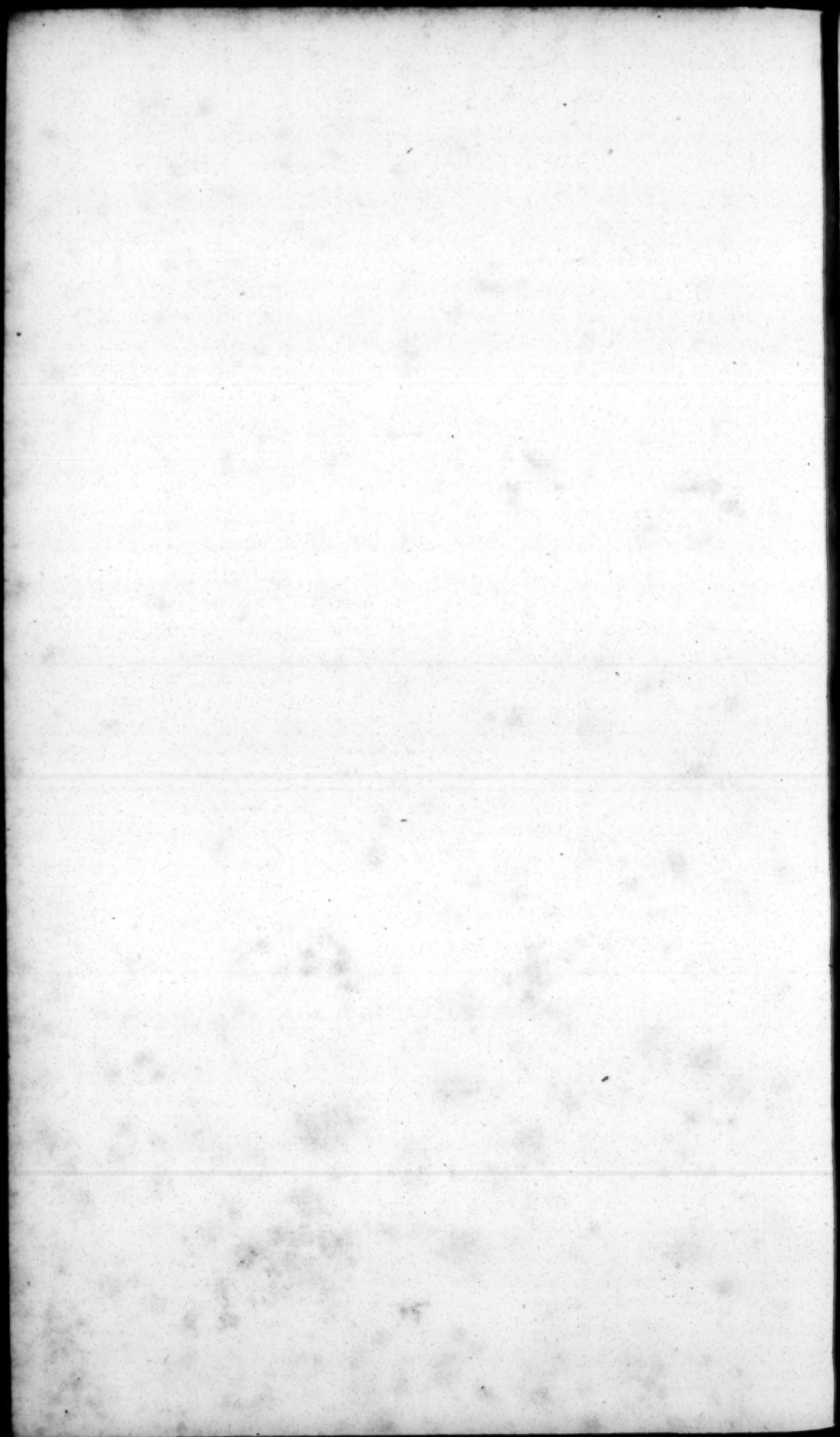
It is no less impossible, that the moon's absolute motion can be owing to a projection given to herself, than that it should be owing to her gravitation toward the earth: for this plain reason; because she has a projectile motion quite different from this, namely round the earth. For nothing

is more impossible, than for a body to move in two directions at the same time. If five hundred projections, all in different directions, were applied at the same time, the projectile would fall into one course, common to them all.

Add to this, that if there can be no real motion, in an adverse direction to absolute motion, unless there be a destruction, or at least, weakening of that *vis inertiae*, which is supposed to be the principle that continues absolute motion; then the projectile course of the moon round the earth, must soon destroy her absolute motion. For every month the moon for near 500,000 miles, struggles in a course, which is in effect, diametrically opposite to the *vis inertiae*, carrying her in another direction. And this cannot happen without continually weakening, and at last wholly destroying it.

For these reasons, unless I can see them fairly removed, I must conclude, that even supposing these principles, assumed by the present philosophy, are real, yet it is impossible to explain the celestial motions by them."

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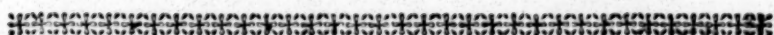




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